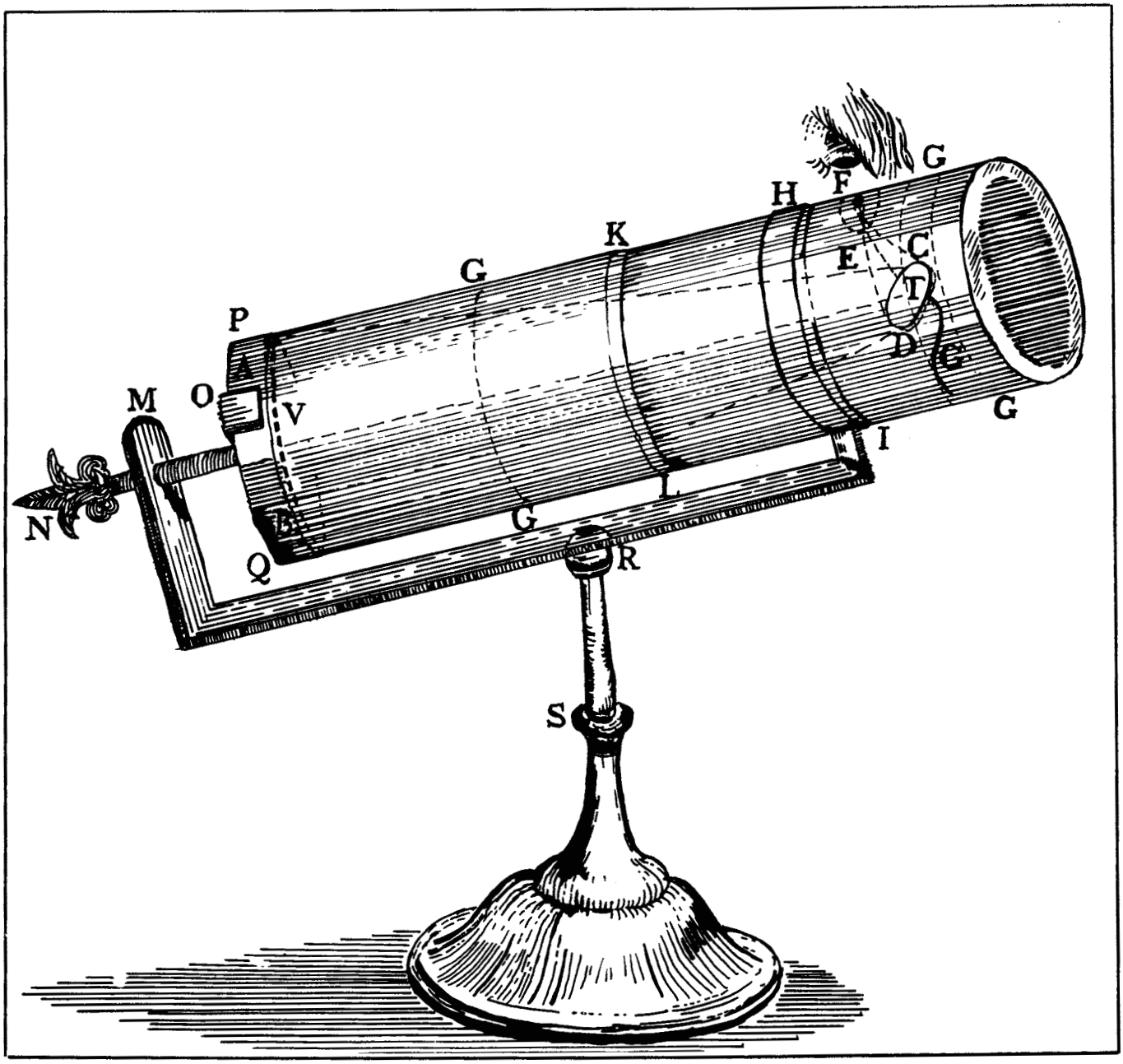
TELESCOPE MAKING 9

ISSN 0190-5570

The magazine *for*, *by*, and *about* telescope makers!

Fall 1980



Astronomy magazine © 2008 Kalmbach Publishing Co. This material may not be reproduced in any form without permission from the publisher. www.Astronomy.com

TELESCOPE MAKING

The magazine *for, by* and *about* telescope makers!

Editor: Richard Berry

Associate Editor: Robert E. Cox

Copy Editor and Editorial Assistant: Katherine M. King

TELESCOPE MAKING (ISSN 0190-5570) is published quarterly by AstroMedia Corp., 411 E. Mason St., P.O. Box 92788, Milwaukee WI 53202.
Copyright © 1980 by AstroMedia Corp., all rights reserved. No part of this issue may be reproduced by any mechanical, photographic or electronic process or otherwise copied for public or private use without written permission of the publisher. The opinions expressed in this magazine are not necessarily those of the publisher or editors.
POSTMASTER: When undeliverable, send form 3579 to publisher. Direct all inquiries, complaints, editorial submissions, and other correspondence to: TELESCOPE MAKING, 411 E. Mason St., P.O. Box 92788, Milwaukee, WI 53202; telephone (414) 276-2689. Not responsible for unsolicited materials. Names and addresses of authors will be printed unless specifically requested otherwise. Subscription price (U.S.): 1 year $8.00; single issues $2.00; other countries: 1 year $9.00, single issues $2.25. Clubs and dealers: Inquire about bulk rates. Typing: Dianne P. Cuneo & Mari Wing; Typesetting: Jane Borth; Advertising: Robert Schmall. Printed by Port Publications, Port Washington, WI.

In this issue...

2 Editorial
3 Letters
4 A New Catadioptric Telescope
by Isaac Newton
6 Newtonian Telescopes
by Richard Berry
14 The Apollo Rendezvous
by Dave Eicher
16 A Poncet With a Difference
by Richard W. Lasher
18 Ronchi Testing
by Sherman Schultz
26 An Observatory and Dome
by Ronald Wisdom
32 Telescopes for the Future
by Kevin Ritschel
38 The Amateur Space Telescope
by Jesse Eichenlaub & David Marat
46 Blue Pages Classified Product Directory

Editorial

A lot of really exciting things are happening in amateur astronomy today. Kevin Ritchel's article "Telescopes for the Future," and the Amateur Space Telescope effort are reflections of that excitement. In this issue I've included, for historical interest, Newton's descriptions and letters as well as a review of hard-to-find technical information on the Newtonian that many people have been asking for. Several important articles didn't make it through the time and space squeeze for this issue; among them Dave Eicher's coverage of Stellafane as well as my write-up on the Midwest Astrofest and Telescope Fair. These will appear in TM #10.

Bob Kestner has asked me to warn anyone trying to work large thin blanks that the back of the blank must be flat. His 25" disk (1⅝" thick) had a cylindrical backside (which goes to show you can't even trust a Blanchard grinder), and the figure kept showing astigmatism. After grinding the back flat with a glass tool, the astigmatism problem disappeared. Thin blanks can be done, but there are some special techniques involved.

Letters in response to the advertising question posed in TM #7 appear in our Letters column. Our ad policy has been shaped by your input, and I thank you for it. Now, here's the policy:

1) Blue Pages classified listings will be available in regular and bold face in a new two column format.

2) Blue Pages display ads are available in three sizes only, maximum of one page per issue per advertiser. Dimensions are: ¼-page, 3 ⅜x4⅝; ½-page, 7x4⅝; full page, 7x9⅝.

3) Each ¼-page of display ad space entitles the advertiser to one free classified listing.

4) Advertising will be accepted only for components, parts, and services. Ads for complete telescopes will not be accepted.

5) Ads must have ruled borders to maintain a neat appearance. Camera-ready art only will be accepted. With the exception of code number changes, no make-up work is available. No reverses or screens available.

6) Rates: Regular listing — first $10, each additional, $1.50; Bold face, first $20, each additional, $2. Display space — ¼-page $35; ½-page, $60; full page, $100. 10% discount for 4X insertion.

7) Ads will appear only in the Blue Pages.

8) Everything having to do with advertising will be handled by Robert Schmall, ASTRONOMY's advertising man.

Well, that about ties it up. I hope that our accepting advertising results in lots of specials and one-of-a-kind items in TM's Blue Pages, as well as information on a broad line of components. The advertisers ought to be hearing from Mr. Schmall in the near future, and we'll all get to see how they respond. They can't beat our rates — or our readership!

Sincerely,

Richard Berry

Richard Berry

Letters

TMT Defunct — But Wait!

Sir / You will find enclosed a letter which I recieved from the publishers of the now defunct *Telescope Making Techniques*. I'm passing this letter along to you so that other TMs who have waited years for Allen Mackintosh to finish a collection of the best articles from the Maksutov Club Circulars, can drop a line to the publisher to insure they meet their goal of 500 subscriptions.

Donald Bowen
17 Wells Rd.
Grauby, CT 06035

The letter follows:

Sir / Since all of the remaining material of TMT is being compiled into a 528 page hard cover book, your check is being returned to you. When the book is completed a notice will be sent to you announcing its availability.

The cost will be $34.75 and we will be setting a goal of 500 (minimum) subscriptions to insure the completion of this major effort. If you have any further questions, please feel free to write me.

Meanwhile when all is complete we will contact you, possibly around mid-March of 1980.

Bill Charles
William Charles Communications
P.O. Box 231
Kinnelon, N.J. 07405

We are looking forward to seeing this book in print.

Mini-Dobs

Sir / I built a Coulter 4¼" f/4 telescope kit and made a disasterous tripod mount for it. Your Dobsonian mount articles inspired me to try a scaled down version. The result far exceeds any hopes I had. My box of eyepieces fits in the bottom and the whole rig is easily carried under one arm. Aiming is a pleasure — smooth with no jitter or backlash. Where aimed it just sits with no creep.

All dimensions were cut approximately in half. ⅜" plywood was used. It was first balanced horizontally by centering the tube, then balanced vertically by screwing a two pound weight to the bottom of the tube box. Two pounds is about right to counter the weight of the eyepiece, eyepiece holder, and finder at any scale.

This half size project required a cash outlay of less than $4, three evenings of puttering, and resulted in a mount that is ideal for this excellent 15" long telescope. Enclosed is a photo of the telescope.

David A. Young
21 Baymeadow Dr.
Nashua, NH 03063

Whew! — When we saw the picture, we thought your daughter built the telescope!

36➤

subscribe!

- TM is published 4 times per year.
- Your subscription will begin with the issue next to be published.
- The current issue and all back issues are available at $2.00 each.
- Payment must accompany your order.
- Domestic Subscription Rate: $8.00 per year; $16.00 for two years
- Foreign Subscription Rate: $9.00 per year; $18.00 for two years

Name: _____

Address: _____

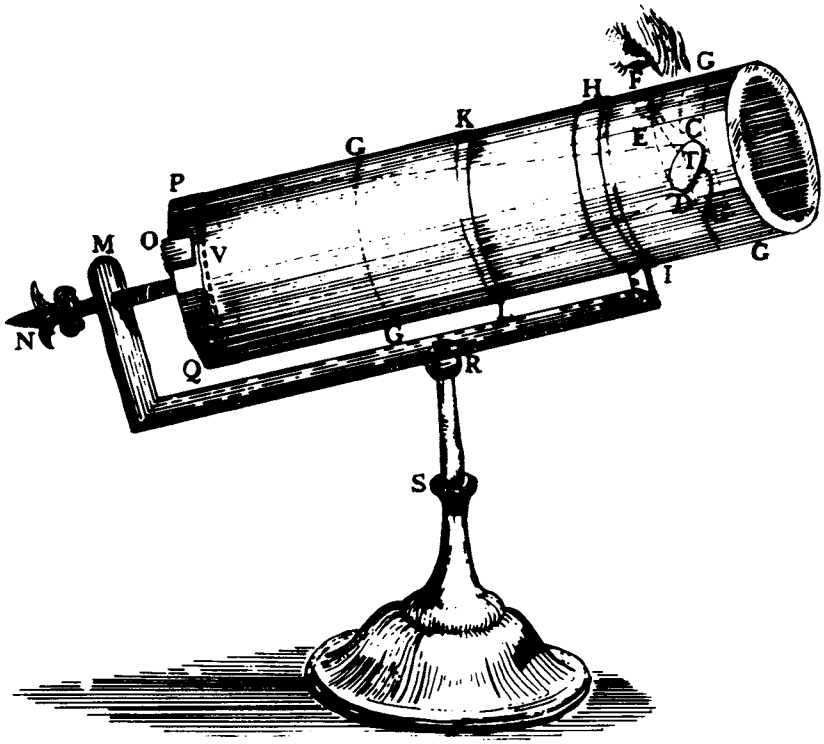
City/State/Zip _____

Mail to:
Telescope Making
411 East Mason Street
P.O. Box 92788
Milwaukee, WI 53202

☐ Enclosed is $8 ($9 foreign) for 1 year of TM.
☐ Enclosed is $16 ($18 foreign) for 2 years of TM.
☐ Please send me the following back issues:

☐ #1 Fall 1978
☐ #2 Winter 1978
☐ #3 Spring 1979
☐ #4 Summer 1979
☐ #5 Fall 1979
☐ #6 Winter 1979/80
☐ #7 Spring 1980
☐ #8 Summer 1980

Foreign subscribers must remit in U.S. funds.



An Account of a New Catadioptrical Telescope, invented by Mr. Newton, F.R.S. and Professor of Mathematics in the University of Cambridge, 1672.

This excellent mathematician having given us, in the Transactions of February last, an account of the cause which induced him to think on reflecting telescopes instead of refracting ones, has thereupon presented the world with an essay of what may be performed by such telescopes; by which it is found, that telescopical tubes may be considerably shortened without prejudice to their magnifying effect. In these letters we have a description of the first reflecting telescope that was ever made, as far as we know.

The idea had indeed been mentioned a few years before, by Mersenne, in a letter to Descartes, who did not approve of it; and again by James Gregory, in his *Optica Promota*, who endeavoured in vain to carry the idea into execution. Those attempts however were suggested by a motive far inferior to that of Newton, being intended, besides shortening the telescope, to avoid the errors arising from the figure of the lenses; whereas that of our author was to obviate the error and inconvenience of the coloured images, and of the unequal refraction of the rays of light; a splendid discovery, which had but just before been made by himself.

This new instrument is composed of two metalline specula, the one concave, (instead of an object glass) the other plain; and also of a small plano-convex eye-glass. The structure of it may be easily imagined that the tube of this telescope is open at the end which respects the object; that the other end is close, where the said concave is laid, and that near the open end there is a flat oval speculum, made as small as may be, the less to obstruct the entrance of the rays of light, and inclined towards the upper part of the tube, where is a little hole furnished with the said eye-glass. So that the rays coming from the object, first fall on the concave placed at the bottom of this tube, and are thence reflected toward the other end of it, where they meet with the flat speculum, obliquely posited, by the reflection of which they are directed to the little plano-convex glass, and so to the spectator's eye, who looking downwards sees the object which the telescope is turned to.

To understand this more distinctly and fully, the reader will observe that AB is the concave speculum, of which the radius or semi-diameter is 12-2/3 or 13 inches. CD another metalline speculum, whose surface is flat and the circumference oval. GD an iron wire, holding a ring of brass, in which the speculum CD is fixed.

F, a small eye glass, flat above, and convex below, of the 12th part of an inch radius, if not less; as the metal collects the sun's rays at 6-1/3 inches distance, and the eye-glass at less then 1/6 of an inch distance from its vertex: besides that the author knew their dimensions by the tools to which they were ground, and particularly measuring the diameter of the hemispherical concave, in which the eye glass was wrought, found it the 6th part of an inch.

GGG, the forepart of the tube, fastened to a brass ring HI, to keep it immoveable. PQKL, the hind part of the tube, fastened to another brass ring PQ. O, an iron hook, fastened to the ring PQ, and furnished with a screw N, thereby to advance or draw back the hind part of the tube, and so by that means to put the specula at their due distace. MQGI, a crooked iron, sustaining the tube, and fastened by the nail R to the ball and socket S, whereby the tube may be turned every way. The centre of the flat speculum CD, must be placed in the same point of the tube's axis, where falls the perpendicular to this axis, drawn to the same from the centre of the little eye-glass, which point is marked as T.

And that the reader may understand in what degree it represents things distinct, and free from colours, and know the aperture by which it admits light, he may compare the distances of the focus E from the vertices of the little eye-glass and concave speculum, that is, EF, 1/6 of an inch, and ETV, 6 1/3 inches, and the ratio will be found as 1 to 38; whereby it appears that the objects will be magnified about 38 times. To which proportion is very consentaneous an observation of the crown on the weather-cock, about 300 feet distant. It appears larger by 2½ times, when seen through this, than through an ordinary telescope of about two feet long. And supposing this ordinary one to magnify 13 or 14 times, as by the description it should, this new one by the experiment must magnify near as much as has been assigned.

Thus far as to the structure of this telescope. Concerning the metalline matter fit for these reflecting speculums, the inventor has also considered the same.

That for a fit metalline substance he would give this caution; that while men seek for a white, hard and durable metalline composition, they resolve not upon such a one as is full of small pores, only discoverable by a microscope. For though such a one may, to appearance, take a good polish, yet the edges of those small pores will wear away faster in the polishing than the other parts of the metal; and so however polished the metal may appear, yet it shall not reflect with such an accurate regularity as it ought to do. Thus tin glass mixed with ordinary bell metal makes it more white, and apt to reflect a greater quantity of light; but its fumes, raised in the fusion like so many aerial bubbles, fill the metal full of those microscopical pores. But white arsenic both blanches the metal, and leaves it solid without any such pores, especially if the fusion has not been too violent. What the Stellate Regulus of Mars or other such like substance will do, deserves particular examination.

Putty, or other such like powder with which it is polished, by the sharp angles of its particles, frets the metal if it be not very fine and fills it full of such small holes as he speaks of. Wherefore care must be taken of that, before judgement be given, whether the metal be throughout the body of it porous or not.

Not having tried many proportions of the arsenic and metal, he does not affirm, which is absolutely best, but thinks there may conveniently be used any quantity of arsenic, equalling in weight between a sixth and eighth part of the copper, a greater proportion making the metal brittle.

The way was this: he first melted the copper alone, then put in the arsenic, which being melted, he stirred them a little together, taking care in the mean time, not to draw in breath near the pernicious fumes. After this, he put in tin, and again as soon as that was melted, which was very suddenly, he stirred them well together, and immediately poured them off. He knows not, whether by letting them stand longer on the fire after the tin was melted, a higher degree of fusion would have made the metal porous, but he thought the way he proceeded to be the safest. He adds, that in the metal which he sent to London, there was no arsenic, but a small proportion of silver; as he remembers one shilling in three ounces of metal. But he thought withal, that the silver did as much harm in making the metal soft, and so less fit to be polished, as good in rendering it white and luminous. At another time he mixed arsenic one ounce, copper six ounces, and tin two ounces: and this an acquaintance of his has, as he intimates, polished better than he did the other.

As to the objection, that with this kind of perspectives, objects are found with difficulty, he answers that this is the inconvenience of all tubes that magnify much; and that after a little use the inconvenience will grow less, seeing that himself could readily enough find any day objects, by knowing which ways they were posited from other objects that he accidentally saw in it; but in the night to find stars, he acknowledges it to be more troublesome, which yet may, in his opinion, be easily remedied by two sights affixed to the iron rod by which the tube is sustained; or by an ordinary perspective glass fastened to the same frame with the tube, and directed towards the same object, as Descartes in his dioptrics has described, for remedying the same inconvenience of his best telescopes.

So far the Inventor's letters touching this instrument; of which having communicated the description to M. Christian Huygens, we received from him an answer to this effect, in a letter of Feb. 13, 1672:

I see by the description you have sent me of Mr. Newton's admirable telescope, that he has well considered the advantage which a concave speculum has above convex glasses in collecting the parallel rays, which certainly, according to the calculation I have made, is very great. Hence it is that he can give a far greater aperture to that speculum, than to an object-glass of the same distance of the focus, and consequently that he can magnify objects much more this way than by an ordinary telescope. Besides by it he avoids an inconvenience which is inseparable from convex object-glasses, which is the obliquity of both their surfaces, which vitiates the refraction of the rays that pass towards the sides of the glass, and does more hurt than men are aware of. Again, by the mere reflection of the metalline speculum there are not so many rays lost, as in glasses which reflect a considerable quantity by each of their surfaces, and besides intercept many of them by the obscurity of their matter.

Mean time the main business will be, to find a matter for this speculum that will bear so good and even a polish as glasses, and a way of giving this polish without vitiating the spherical figure. Hitherto I have found no specula that had near so good a polish as glass; and if M. Newton has not already found a way to make it better than ordinarily I apprehend, his telescopes will not so well distinguish objects as those with glasses. But it is worth while to search for a remedy to this inconveniece, and I despair not of finding one. I believe that M. Newton has not been without considering the advantage which a parabolical speculum would have above a spherical one in this construction; but that he despairs, as well as I do, of working other surfaces than spherical ones with due exactness; though else it be more easy to make a parabolical than eliptical or hyperbolical ones, by reason of a certain propriety of the parabolic conoid, which is, that all the sections parallel to the axis make the same parabola.

Concerning the grinding parabolical conoids, Mr. Newton says, in a letter of Feb. 20, 1671, that though he, with him, despairs of performing that work by geometrical rules, yet he doubts not but that the thing may in some measure be accomplished by mechanical devices.

Another extract of a letter, received very lately from the Inventor of its new Telescope, from Cambridge:

In my last letter I gave you occasion to suspect, that the instrument which I sent you is in some respect or other indisposed, or that the metals are tarnished. And, by your letter of March 16, I am fully confirmed in that opinion. For while I had it, it represeted the moon in some parts of it as distictly as other telescopes usually do which magnify as much as that. Yet I very well know, that the instrument has its imperfections, both in the composition of the metal, and in its being badly cast, as you may perceive by a scabrous place near the middle of the metal of it on the polished side, and also in the figure of that metal near the scabrous place. And in all those respects that instrument is capable of further improvement.

You seem to intimate, that the proportion of 38 to 1 holds only for its magnifying objects at small distances. But if for such distances, suppose 500 feet, it magnify at that rate, by the rules of optics it must, for the greatest distance imaginable, magnify more than 37¾ to 1; which is so inconsiderable a diminishing, that it may be even then as 38 to 1.

Here is made another instrument like the former, which does very well. Yesterday I compared it with a 6-foot telescope, and found it not only to magnify more, but also more distinctly. And to day I found, that I could read in one of the *Philosophical Transactions*, placed in the sun's light, as 100 feet distance, and that at 120 feet I could discern some of the words. When I made this trial, its aperture (defined next the eye) was equivalent to more than an inch and a third part of the object metal. This may be of some use to those that shall endeavour anything in reflections; for hereby they will in some measure be enabled to judge of the goodness of their instruments, &c.

Isaac Newton
(reprinted from the
Philosophical Transactions
of the Royal Society
of London)

Newtonian Telescopes

The simplest and most popular homebuilt telescopes are Newtonians. Frequently, however, the builders lack important information necessary to make full use of the Newtonian's capabilities, especially for photography. That information is found in this article.

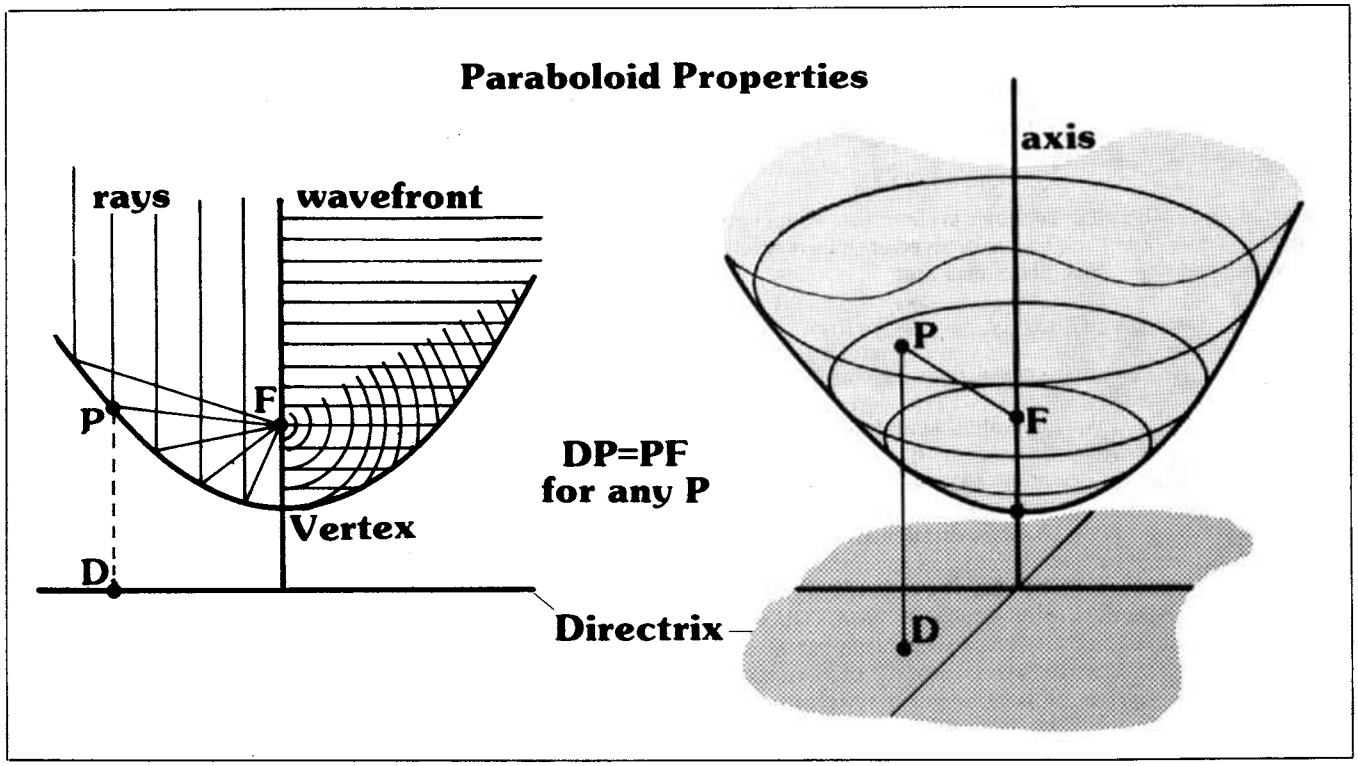
The Newtonian has two elements, a paraboloidal primary mirror and a plane secondary mirror. The paraboloid is the image forming element, focusing the plane wavefront from a distant source, such as a star, into a small region whose size is limited only by the diffraction of light. The plane mirror is for convenience only; it deflects the focus of the light outside the tube of the telescope. When used with an eyepiece, the instrument is afocal, since parallel light enters and exits the system.

Properties of Paraboloidal Mirrors

A paraboloid is the locus of points lying equidistant between a plane called the directrix and a point called the focus. The line that passes through the focus and is normal to the directrix plane is called the axis. The vertex lies at the intersection of the paraboloid and its axis. If a mirror is made in a paraboloidal form, parallel light from a distant source, therefore having a plane wavefront, propagating along the optical axis, will be reflected to the focus. The path length along all the rays will be exactly the same, a condition necessary for a diffraction limited image.

The equation of a paraboloid of revolution with its axis lying on the x-axis is:

$$x = y^2/4f + z^2/4f$$



The paraboloid is one a a series of related "conic" surfaces, so called because their two-dimensional axial cross-sections are sections of a cone. Expressed in a form appropriate for optical calculations, the general equation of a conic section is:

$$y^2 - 2rx + px^2 = 0$$

or:

$$x = y^2/2r + py^4/8r^3 + 3p^2y^6/48r^5 + 15p^3y^8/384r^7 + \ldots$$

where x is measured along the optical axis, y represents the distance from the axis, r is the radius of a sphere tangent to the paraboloid at the vertex (i.e., twice the focal length), and $p = 1-e^2$ (p=1 for a circle, p between 1 and 0 for an ellipse, p=0 for a parabola, p is negative for a hyperbola) where e is the conic's eccentricity. Note that all the terms in p drop out for a parabola.

The "speed" of a mirror, N, (also called its "focal ratio" or "f/ratio"), is defined as the ratio of its focal length, f, to its diameter, D:

$$N = f/D$$

Mirrors for telescopes are seldom made faster than f/4 because of limiting aberrations, and, for practical reasons of length, seldom slower than f/12.

Axial Star Images

The image of a point source (i.e., a star) formed by a perfect paraboloid consists of a central bright spot surrounded by equally spaced alternate dark and bright rings. 83.8% of the energy lies in the central bright Airy disc, 7.1% in the first bright ring, 2.8 in the second bright ring, 1.5% in the third bright ring, 1.0% in the fourth bright ring. The angular diameter in radians, beta, of the first dark ring is:

$$\text{beta} = 2.44\ \text{lambda}/D$$

where D is the aperture of the paraboloid, and lambda the effective wavelength of the light. Lambda and D must be expressed in the same units.

The angular resolution of the system depends on the criterion adopted for "resolution," or separation of two equal star images. Rayleigh's criterion, that the "valley" between two illumination peaks be 0.71 the intensity of the central spots, leads to an angular resolution, in radians, of:

$$R_{Rayleigh} = 1.22\ \text{lambda}/D$$

The Sparrow criterion specifies that the "valley" illumination equal the peaks:

$$R_{Sparrow} = \text{lambda}/D$$

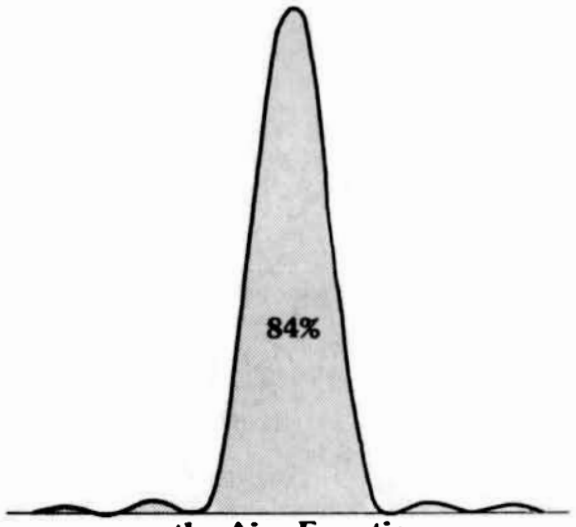
For visual use (with an effective wavelength at 0.55 microns, or yellow-green light), and D expressed in millimeters, the resolution criteria, in seconds of arc, are:

Rayleigh criterion = 140/D
Sparrow criterion = 115/D

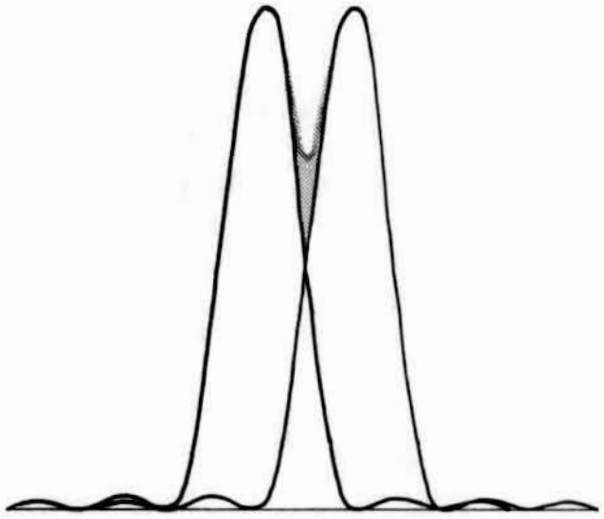
A system in which the optical path difference does not exceed ¼-lambda is often considered to perform nearly as well as a perfect system. Given a smooth ¼-lambda error in the path lengths of the converging wavefront, the energy contained inside the first dark ring is approximately 68% of the total. The rest of the energy is thrown into the rings, resulting in decreased image contrast. A 30% central obstruction has the same effect.

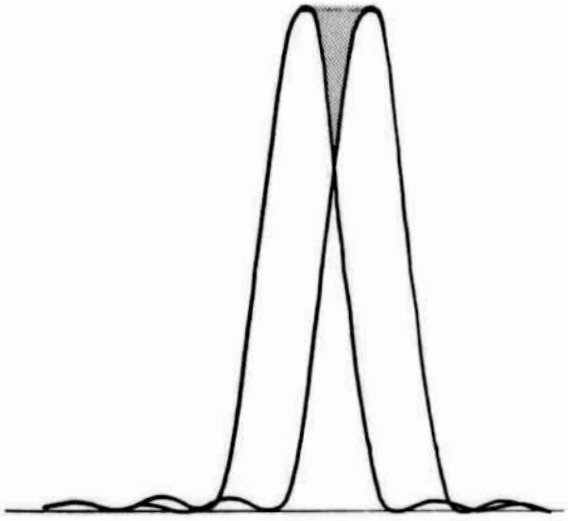
Aberrations of the Newtonian

Spherical aberration A spherical mirror used in a Newtonian telescope reflects light striking different zones of the mirror to different focal points. In undercorrected spherical aberration, paraxial rays (reflected from the mirror near the axis) focus farther from the mirror than marginal rays. A spherical mirror displays undercorrected spherical aberration



the Airy Function


the Rayleigh Criterion


the Sparrow Criterion

when used in a Newtonian telescope. While paraboloidal mirrors have no spherical aberration, spherical mirrors function well in Newtonians when they depart from a paraboloid by less than ¼-lambda of optical path difference. This occurs when the aperture, D, and the focal length, f, in millimeters, are related as:

$$f = 1.52\ D^{4/3}$$

Parabolizing this mirror is thus unnecessary for any focal ratio greater than:

$$N = 1.52\ D^{1/3}$$

(1.92 for ⅛-wave, 2.52 for 1/16-wave)

Following these criteria exactly will introduce a full ¼-lambda error in the wavefront with accompanying reduced contrast in observing fine detail. For best results, f and N should be greater than indicated by the formulae.

The angular blur due to the spherical aberration of a sphere, s, in radians, is:

$$s = 1/128(f\#)^3$$

and the blur diameter, S, is:

$$S = D/128(f\#)^2$$

where D is the aperture of the system.

Coma The image formed by a paraboloidal mirror is larger for the outer zones than it is for the inner zones. On the optical axis, the images formed by all zones are superimposed and the combined image is perfect. Away from the axis, the outer zones of the mirror focus light further from the axis than paraxial zones. Coma is asymmetric: light from the paraxial parts of the mirror form a tip of the comatic image, the outer zones produce a relatively faint "tail" extending away from the optical axis.

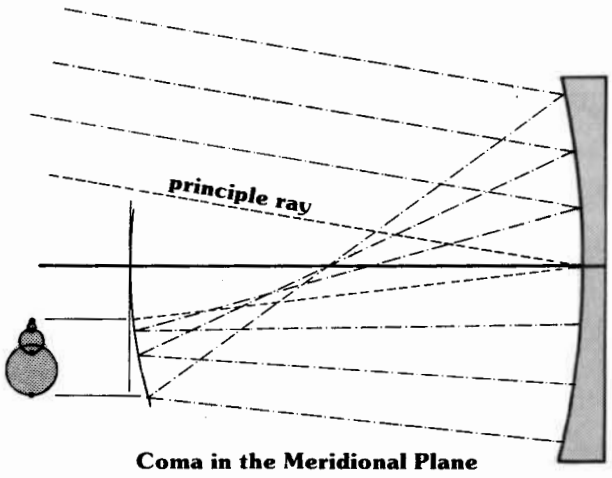
Sagittal coma is formed by rays from the sagittal plane of the mirror. 50% to 60% of the light in a comatic image is contained in the sagittal coma. Its angular length, c_s, in the sagittal plane, in radians, is:

$$c_s = (\text{theta})/16N^2)$$

where N is the focal ratio and theta is the off-axis angle in radians. The length of the sagittal comatic blur is:

$$C_s = y/16N^2$$

where y is the off-axis distance. C_s will be in the same units as y.



Coma in the Meridional Plane

Tangential coma is formed by rays from the meridional plane (i.e., "the plane of the page"). Tangential coma is three times as long as sagittal coma:

$$c_t = 3(\text{theta})/16N^2$$

$$C_t = 3y/16N^2$$

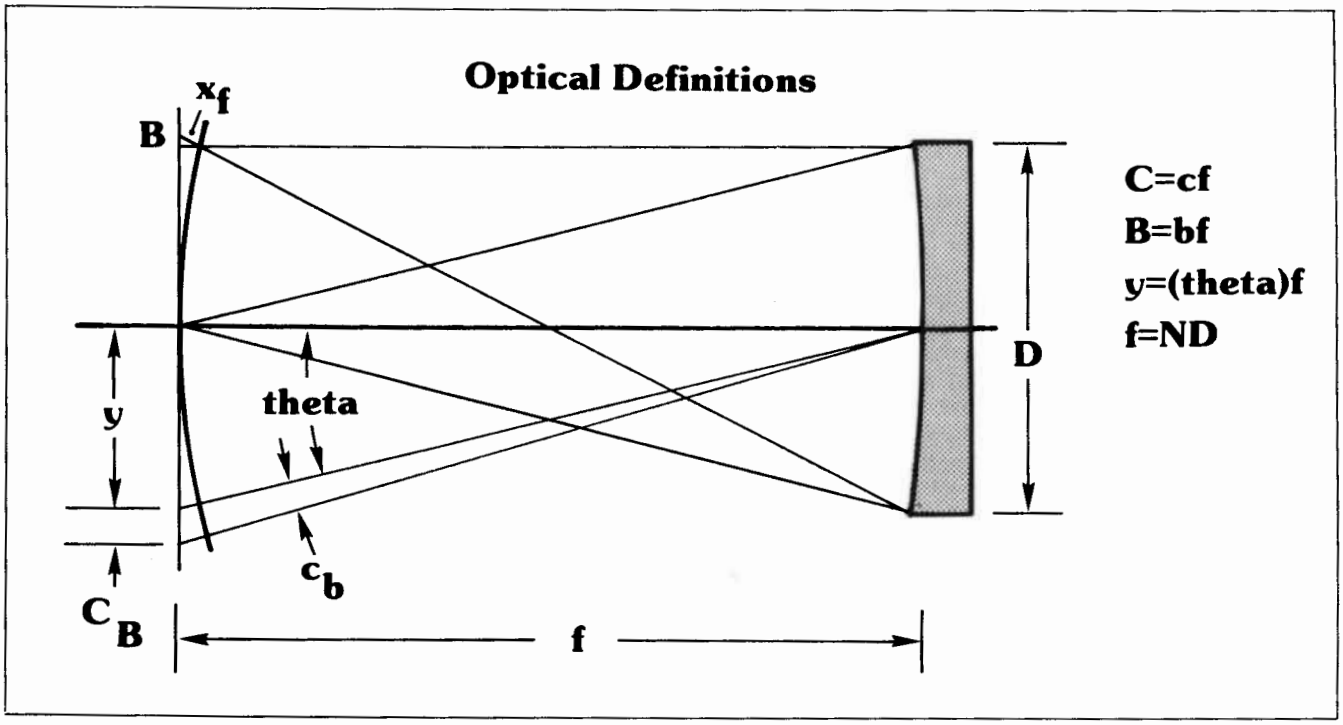
The width of the comatic blur is 2/3 the length of tangential coma.

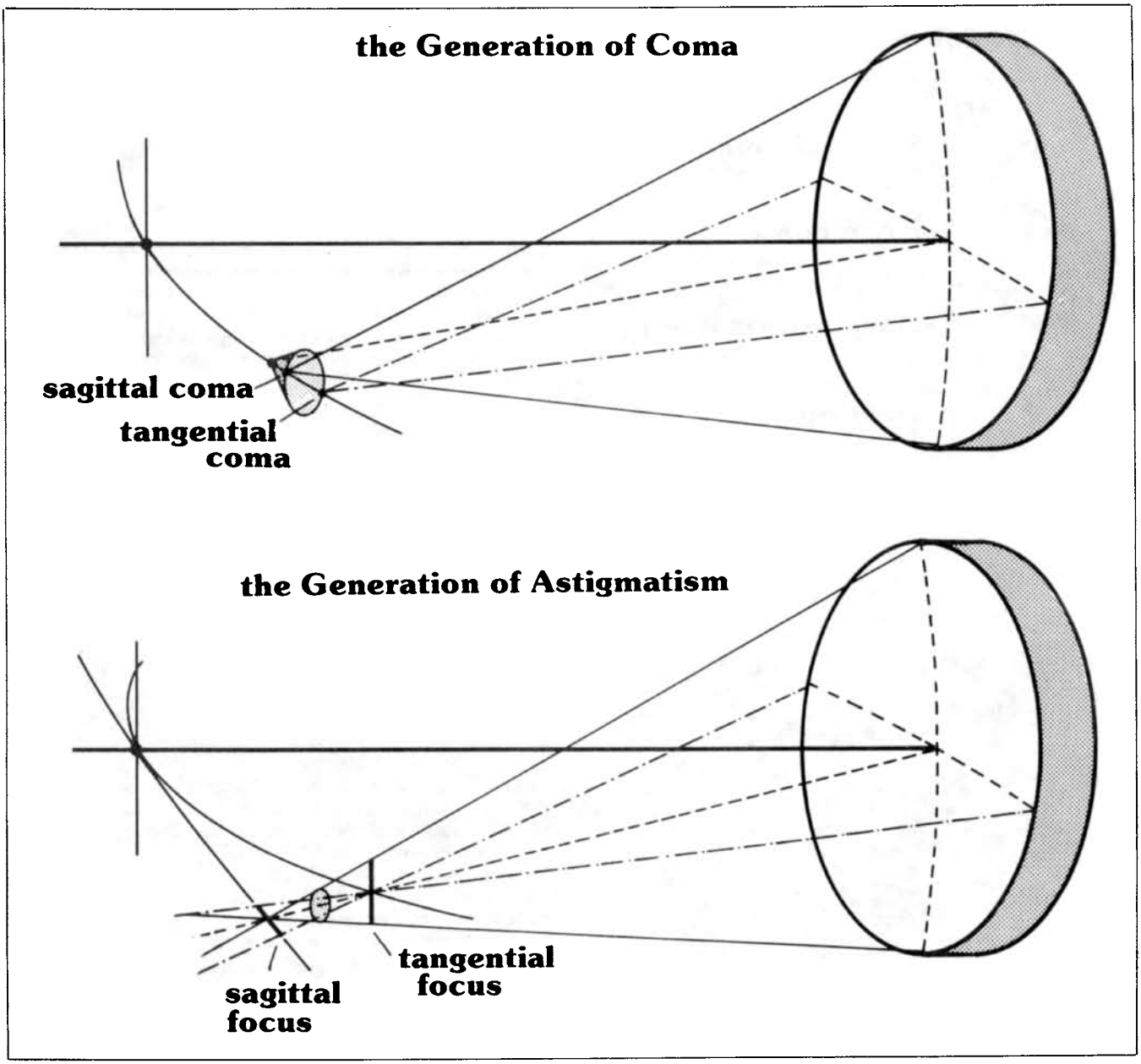
The diameter of the coma-free field (i.e., the field over which coma does not introduce more than a ¼-lambda error) is:

$$d_{\text{coma-free}} = 0.011N^3$$

where the coma-free field is in millimeters.

Astigmatism Because off-axis rays from different points in a zone of the mirror do not intersect in the same plane, oblique astigmatism is present in images formed by





paraboloids. Astigmatism is a symmetrical aberration, hence not as bothersome as coma in many applications.

In a Newtonian with the stop at the mirror (usually the case), rays in the meridional plane reach focus on a surface concave to the mirror with a radius of f/2; this is the tangential focal surface. Rays from the sagittal plane intersect at the sagittal focal surface, which lies in the focal plane. The surface of best focus is a sphere of radius f, and concave toward the mirror.

The angular blur, b, due to astigmatism is:

$$b = (\text{theta})^2(1-L/f)/2N$$

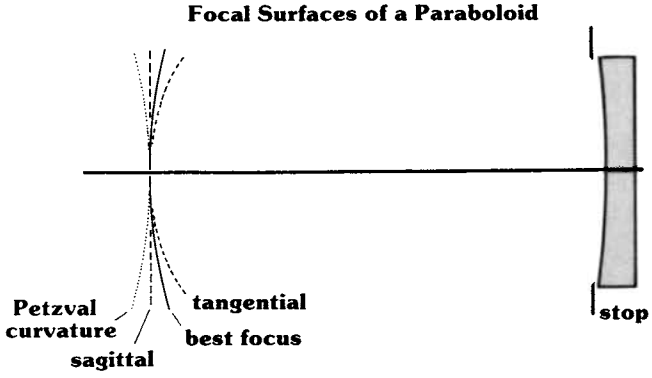
L is the distance between the mirror and the aperture stop (entrance pupil) of the telescope. If L= f, that is, if the stop lies one focal distance before the mirror, astigmatism is zero.

For the normal case in homebuilt Newtonian telescopes, where L=0, (i.e., the edge of the mirror forms its own aperture stop), the formula reduces to:

$$b = (\text{theta})^2/2N$$

The smallest astigmatic blur will have a diameter, B, of:

$$B = y^2/2fN$$



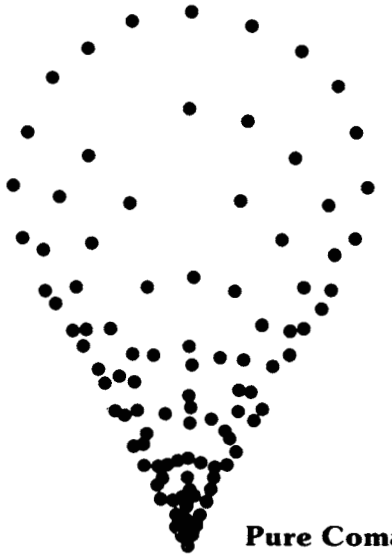
Diffraction Patterns

2 waves of coma

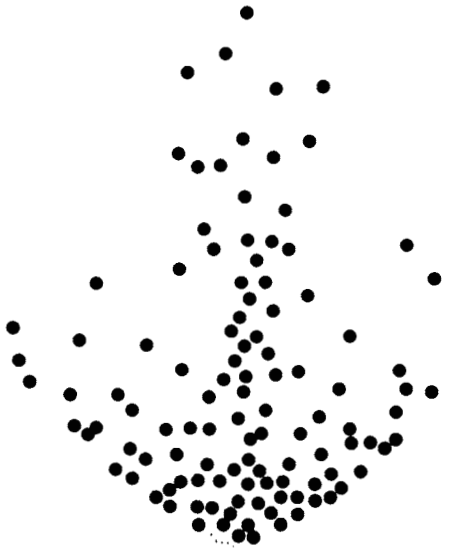
¼-wave coma

¼-wave astigmatism

perfect optics



Pure Coma



Coma plus Astigmatism

The lengths of the sagittal and tangential focal lines are twice the diameter of the blur circle.

Coma grows linearly with the off-axis angle, but astigmatism grows with the square of the off-axis angle. Coma dominates near the axis, especially with fast mirrors, while astigmatism is important at greater axial distances. With amateur instruments, coma and astigmatism are of comparable importance. For very large Newtonians, astigmatism is unimportant.

Field Curvature The surface of best focus is a sphere of radius f concave toward the mirror. It lies equidistant between the two astigmatic foci. Even when astigmatism is eliminated with an appropriate stop, the comatic image lies on this sphere. For visual use, field curvature is usually unimportant, but it may blur images at the edges of wide-angle fields.

To obtain a larger photographic field, the film may be moved toward the mirror by a distance x_f :

$$x_f = y^2/2f$$

where y is field radius in focus and f, the focal length. For a "best compromise" focus, chose y to be about half the intended radius of the field.

The maximum shift is determined by the defocusing of the axial images to a blur with diameter B:

$$x_f = NB$$

Because of field curvature, short-focus mirrors have smaller useable fields than longer focus mirrors of the same f/ratio. This is why very small RFTs are frequently poor for astrophotography.

The Newtonian Diagonal

Newtonians employ a flat mirror, called the diagonal mirror, suspended near the front of the tube to reflect the optical axis out the side of the telescope tube for access by the observer. The flat is usually inclined at a 45° angle to the optical axis, so that the beam exits pendicular to the tube axis. When so placed, the diagonal mirror's shape is an ellipse with an axial ratio (major to minor) of 1.414 to 1.

Size The diagonal obstructs light entering the telescope and produces unwanted effects (less light in the Airy disk and more in the rings) in the star image. It should, therefore, be no larger than necessary to illuminate the desired field of view.

The minimum size diagonal capable of fully illuminating only the optical axis has a minor axis, a_{min}, of:

$$a_{min} = c/N$$

where c is the distance from the focal plane to the diagonal. This, however, is unlikely to be satisfactory.

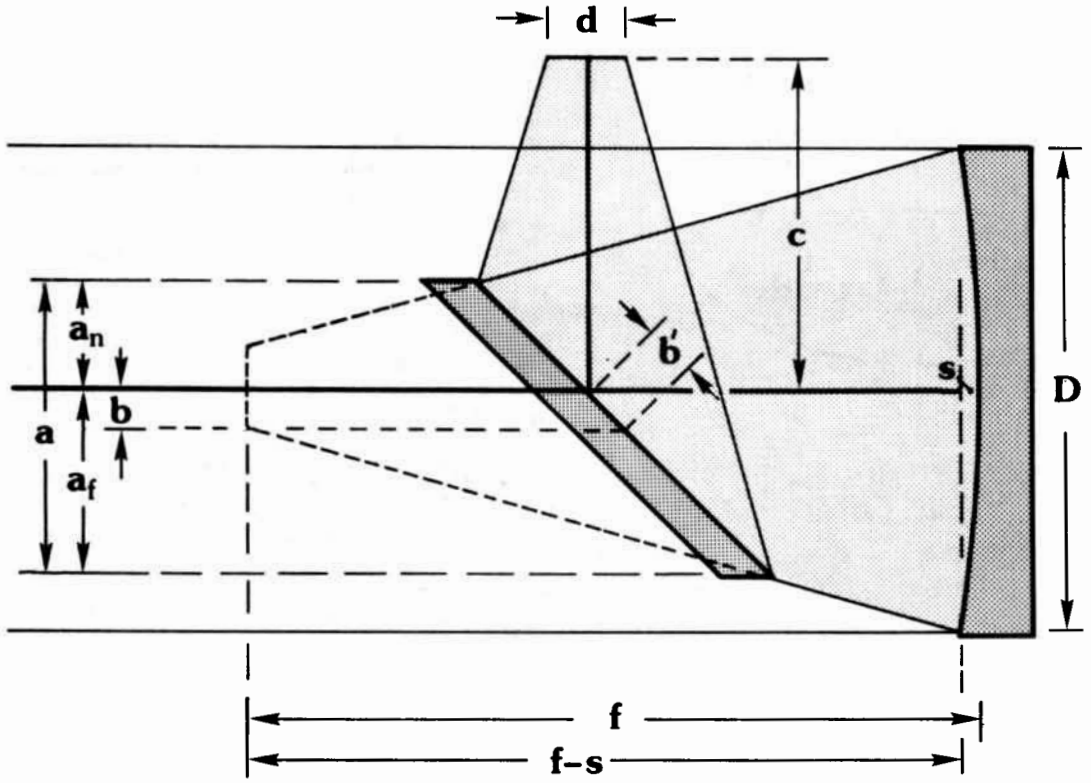
The extent of the fully illuminated field is dependent on the type of observation the telescope is intended for. Considerable light falloff is tolerable at the edges of the field in most kinds of visual observing, so the fully illuminated field may be chosen quite conservatively — on the order of 6mm. The light loss at the edge of 25mm field is then typicaly 0.5 magnitude, or 40%. Visually, this is unimportant.

A more generous criterion frequently taken is 0.5°, the diameter of the full moon, about 1/115 of the focal length. This criterion is generally satisfactory for casual deep-sky photography.

For serious deep-sky photography, where high-contrast negative materials and high-contrast printing may be employed to amplify very small contrast differences, the entire photographic field should be fully illuminated. The short axis of a 35mm film frame is 24mm, the long axis is 36mm, and the diagonal measurement is 43mm.

For a linear field of view, d, the diagonal minor axis size, a, is approximately:

$$a = d + c/N - cd/f$$



the Newtonian Diagonal: Size and Placement

The major axis of the diagonal, a′, is:

$$a' = 1.414a$$

When buying commercial diagonal mirrors, the desired size is not always available.

Shift Because one side of the diagonal is nearer the eyepiece than the other, the illuminated field will not be symmetrically placed about the optical axis unless the diagonal is shifted a short distance, b, away from the eyepiece. For small telescopes, the shift may be ignored; but for larger instruments or photographic telescopes, care should be taken to place the diagonal correctly.

The shift is calculated from a_n and a_f, the projected major axes of the near and far sides of the diagonal respectively, by redistributing its total length between them:

$$b = (a_f - a_n)/2$$

The minor axis of the diagonal is the sum of the two projected partial major axes:

$$a = a_f + a_n$$

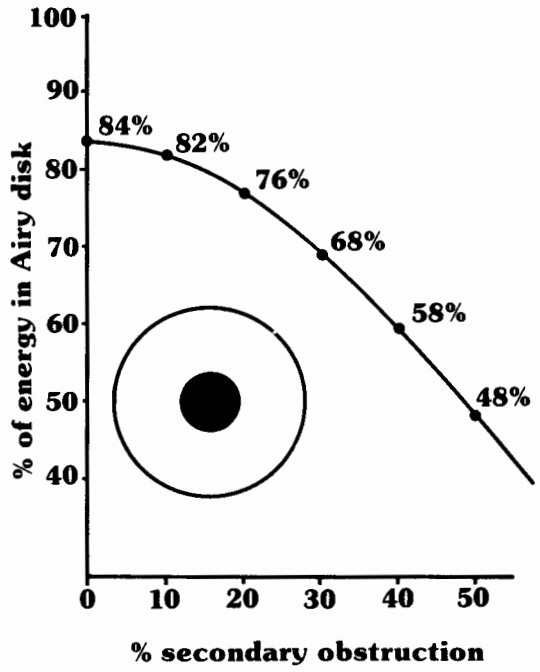
These are calculated with the help of the auxiliary quantities P, Q, and R:

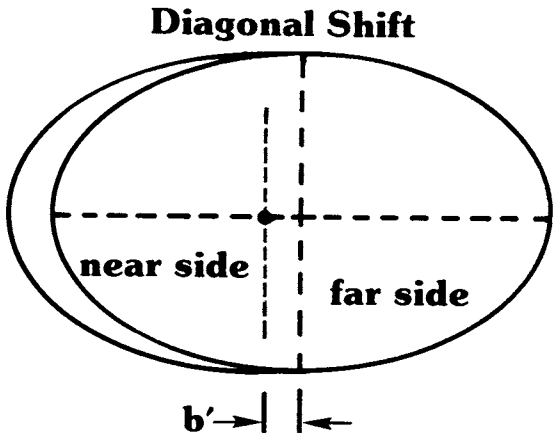
$$a_n = P/Q$$

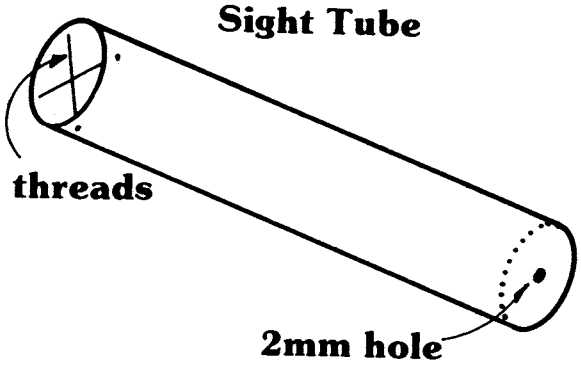
$$a_f = P/R$$

$$P = d(f-s) + c(D-d)$$
$$Q = 2(f-s) - (D-d)$$
$$R = 2(f-s) + (D-d)$$

where D is the diameter of the primary mirror; d the diameter of the field; f, the focal length; s, the sagitta of the mirror (i.e., $r^2/2R$); and c, the axis to diagonal distance.







Measured along the surface of the diagonal, the shift, b', is:

$$b' = 1.414b$$

To minimize the size of the diagonal, it is clearly important to keep c as small as possible. So-called "low-profile" focusers serve this need.

Vignetting

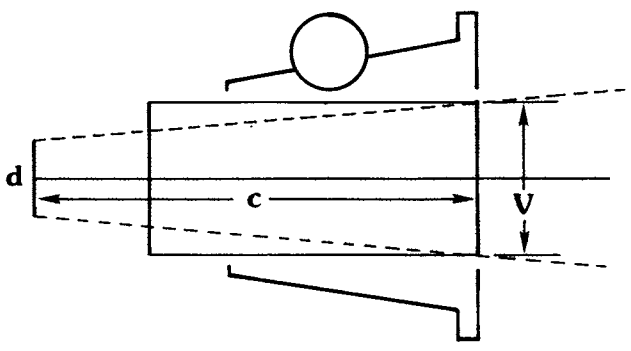
Focuser Vignetting The tube of the focuser may block some marginal rays from the mirror and hence reduce edge illumination. Especially for serious photographic applications of the Newtonian, the minimum allowable internal diameter, V, of the focuser tube at distance, c, from the focal plane, should be:

$$V = d + c/N$$

Tube Vignetting The telescope tube may block incoming starlight before it reaches the mirror. The minimum allowable internal diameter of the tube, t, at distance along the tube from the mirror, T, should be:

$$t = D + dT/f$$

Focuser Vignetting



Alignment

The most common method of aligning a Newtonian telescope consists of fiddling until the edges of all the optical elements appear concentric through the empty focuser tube. With small, slow primary mirrors this works reasonably well. For larger, faster optics, more care is required. The following method (Ralph Dakin's) is quick, accurate, and can be done without reference to the stars.

1) Mark the Primary Aligment of a Newtonian for good axial imagery requires only that the optical axes of the eyepiece and the primary mirror be coincident. Since the vertex of any paraboloid is normal to the optical axis, an observer anywhere on the optical axis must see an image of his own eye at the center of the mirror. If the center of the mirror is marked, the axis of the primary is simple to locate. This may be very neatly done with a spot of black enamel paint (or adhesive tape) approximately 6mm in diameter.

2) Mark the Diagonal The intersection point of the optical axis with the surface of the diagonal by the amount b' from the mechanical center of the diagonal must be marked on the diagonal for alignment. The shift is in the direction of the eyepiece.

For observatory telescopes, the intersection point can be marked with crossed white cotton threads which are removed after alignment is completed.

For portable telescopes, a permanent mark should be made on the diagonal. Paint or India ink may be used to make a tiny spot. This spot, no more than 0.5mm in diameter, will block no light on-axis, but will block a small amount of light and cause some diffraction off the optical axis. However, obtaining proper alignment with every set-up of the telescope is important enough to justify the problems introduced.

3) Build a Sight Tube It is necessary to define the optical axis of the eyepiece. Make a sight tube the same diameter as the eyepieces and 150mm to 200mm long. At one end, place accurately centered cross-wires and at the other a centered 2mm diameter hole. Check that the cross-wires are accurately coincident with the mechanical axis of the tube by placing the tube on vee blocks and rotating it. The sight line must remain constant.

4) Offset the Diagonal Shift the mechanical axis of the diagonal mirror the distance b away from the eyepiece holder. This can be done with an accurate ruler or measuring tape. The diagonal axis should be accurately centered in the plane perpendicular to the focuser.

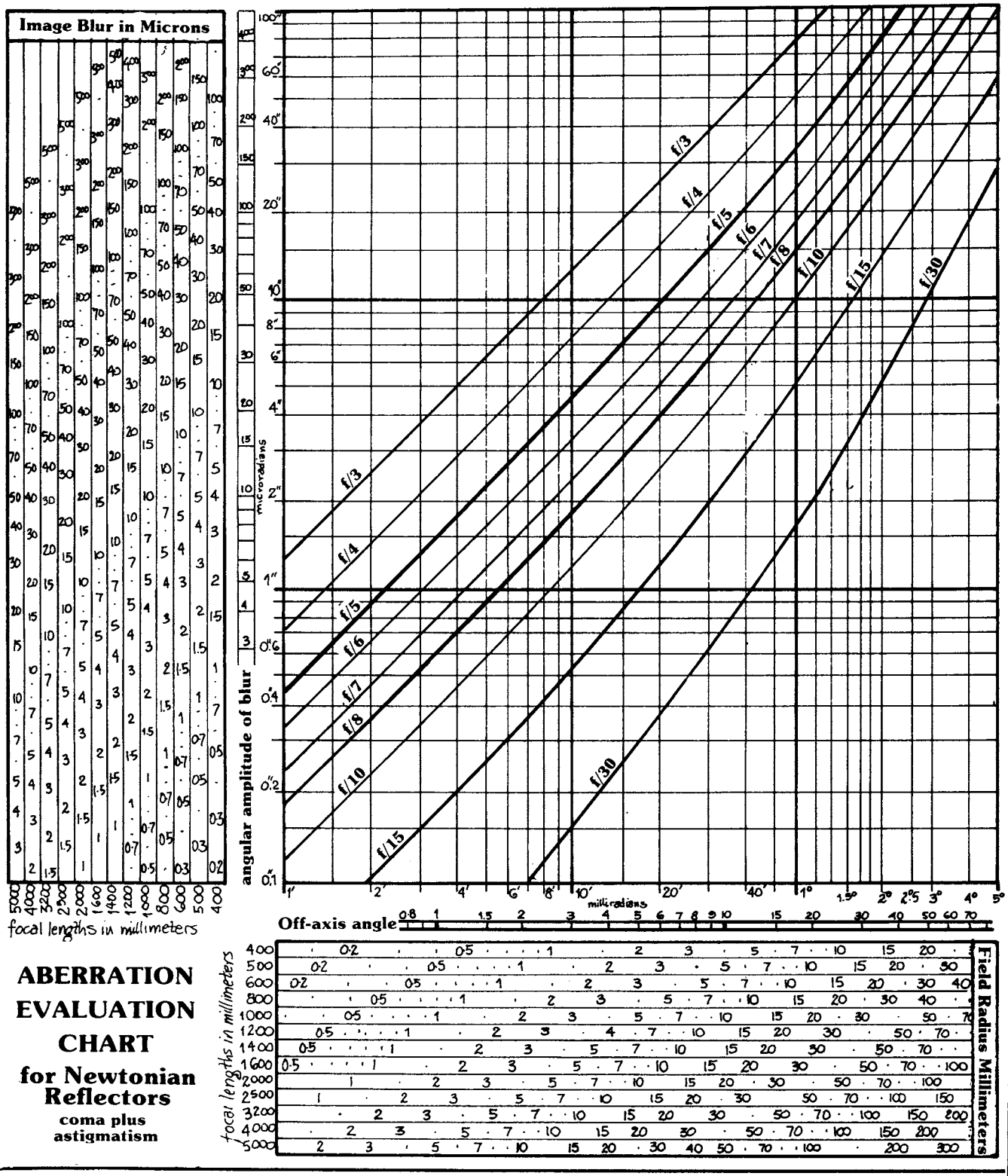
5) Center the Diagonal Mark Place the sight tube in the focuser. Move the diagonal longitudinally until the diagonal mark lies behind the cross-wires. If the focuser is not accurately seated on the tube, this will not be possible. It will then be necessary to shim or otherwise mechanically align the focuser.

6) Center the Primary Spot Tilt and rotate the diagonal by its adjustment screws until the spot on the primary mirror falls behind the cross-wires.

7) Center the Image of the Cross-Wires Tilt the primary mirror until the image of the sight tube's cross wires falls under the cross-wires. The optical axis of the primary mirror is now coincident with the axis of the sight tube, and therefore with eyepieces placed in the focuser. The alignment can be quickly and easily checked each time a portable telescope is set up.

Astrophotography with Newtonians

Newtonians are very powerful instruments for deep-sky astrophotography, but their fields are limited by coma,



ABERRATION EVALUATION CHART

for Newtonian Reflectors

coma plus astigmatism

astigmatism, and focal surface curvature. In designing a photographic telescope, care should be taken to calculate the blur diameters to be expected at the edge of the field. For quick evaluation of a system's performance, consult the Aberration Evaluation Chart. This shows the angular blur versus field angle for f/ratios from f/3 to f/30 as well as what total linear blur can be expected for focal lengths ranging from 400 to 5000mm. Note that the chart tends to overestimate the blur since what is shown is the sum of tangential coma and astigmatism. On fast films, faint star images will show only the sagittal coma blur, though brighter stars may show the full tangential coma blur. 100 microns represents a reasonably acceptable upper limit for image blur at the edge of the Newtonian field.

.....

We expect to carry further and more detailed information on the Newtonian and other optical systems in future issues of TM.

Apollo Rendezvous and Telescope Fair 1980

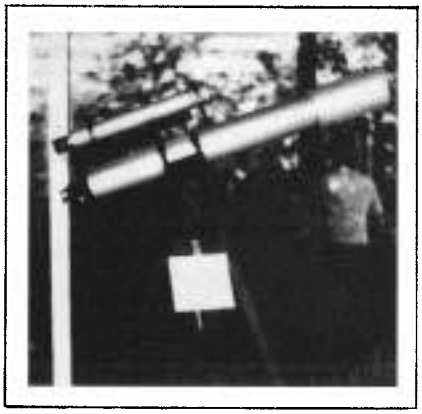
This year on June 13th and 14th, the Apollo Rendezvous and Telescope Fair celebrated its tenth anniversary with a variety of talks, telescopes, and exhibits. For the fifth year in a row, I packed up my weekend gear and headed for the LaQuinta Motel in Dayton, Ohio, about 50 miles from my house and about two from the Dayton Museum of Natural History, where the gathering was held.

Several things were different this year, most notably the absence of Roger Hoefer who for the past nine years as Curator of Astronomy at the museum had helped to form and operate Rendezvous. Roger had moved last fall back to his hometown in Oklahoma to operate a grocery store. Also — somehow — this year it didn't rain as it had at every Rendezvous in memory. Even though Rendezvous seemed rather strange this year, I started off with the

Above: Gary Frey's 8" f/6 Neutonian — a mechanical masterpiece.
Left: Doug Wereb's 6" Newtonian with a home-built mount.
Below: Nick Picciano brought his 10" f/7.7 Dobsonian.

usual anticipation and enthusiasm, sure to meet many new people and have a good time.

The convention this year was chaired by Jim Reist, President of the Miami Valley Astronomical Society (the group that sponsors the event), and Art Goss,



Mark Hall and Charles Roberts brought an aluminum-tubed 3¼″ refractor.

Vice-President of the group. Rendezvous is generally thought of as the third largest gathering of TMs (after Stellafane and Riverside), although attendance was down somewhat this year — to about 175. Sixteen telescopes were entered in the "competition," which is actually more of an informal setup than at other conventions. Awards are given to virtually everyone, and there is no strict mechanical or optical judging. The emphasis is on the exchange of useful ideas rather than competition, and that goal is usually accomplished.

On Friday night, the usual informal slide presentation was held. Amateurs from several states informed us of their observing activities for the last year. Several exhibits were set up in the upstairs room of the Apollo Observatory (which houses the 19⅜″ Dall-Kirkham written up in TM#3), including a computer display by Steve Smith of Cleveland, which used a Radio-Shack TRS-80 outfit to display planetary motions, telescope data, etc. The Warren Astronomical Society of Michigan displayed some of their latest photographic efforts, and Ed Jones of Dayton showed his automatic platform for taking telephoto shots of the sky — a device that, with the use of a spring mechanism, would automatically track for several hours. Dick Wessling of Milford, Ohio displayed some fantastic planetary photos, and to cover the other end of things, I sponsored a display of deep-sky photos to help promote *Deep Sky Monthly*.

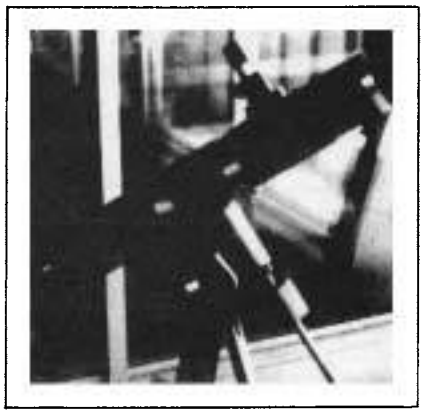
On Saturday morning the telescopes were set up during a series of talks. I chose to hang around the scopes, gather some photos, and talk to a number of people. Two solar telescopes attracted a great deal of attention and provided spectacular views of the Sun. John Phelps of Orland Park, Illinois, brought a 2″ refractor fitted with a Tuthill H-alpha filter. It yielded breathtaking views of several flares and prominences. Dick Wessling had brought a beautiful yellow 4″ refractor fitted with a true-color filter to provide us with a view of a yellow Sun and several large sunspot groups.

Other outstanding scopes included Nick Picciano's 10″ f/7.7 Dobsonian (the only Dobson mounting present), Gary Frey's outstanding 8″ f/6 Newtonian which was fitted with many electronic accessories, and Jack Roach's 6″ Newtonian mounted on a sturdy homemade fork mount. Two historical scopes from Columbus were brought by Brent Archinal (a 5″ f/15 brass refractor) and Doug Wereb (a 4″ Clark made in 1881).

The afternoon paper session was especially interesting to me as a deep-sky nut — Brent Archinal's talk on the Columbus Astronomical Society's Messier Marathon. The group spotted 107 M-objects in one night in early April, with about a dozen people involved, using the 32″ telescope at Perkins Observatory in Delaware, Ohio. Ed Jones presented "A New Drive for Astrophotography" in which he detailed his homemade mounting, and Frank Sutter of Dayton detailed the 1980 total eclipse in India.

One especially notable talk was presented by Dick Suiter of Columbus: "Making Telescopes: A Primer for Real People." He maintains that there are two basic types of TMs: those who are the beginners and are confused about complex statements in the TM books, and those who make the confusing statements in the TM books. The talk was good fun, and offered some real suggestions for constructing modern designs. To top off the afternoon festivities, a marvelous film of the 1979 eclipse in Canada was shown, produced by the National Film Board of Canada. The film follows a group from the Warren Astronomical Society to Brandon, Manitoba, featuring Pete Kwentus, Lou Faix, the late John Searles, and Steve and Sue Rismiller. The film was excellent, and certainly a milestone achievement for an astronomical society.

John Phelps brought his 2″ H-alpha refractor.



Robert Rouhier's 4″ Schmidt-Newtonian

The evening address was presented by Dr. Kenneth Kissell, who is the Senior Scientist for Reconnaissance and Weapons Delivery at Wright-Patterson Air Force Base in Dayton. The address was entitled "The New Imaging of Our Solar Neighbors" and presented new techniques and data which have recently been developed and discovered. After the interesting address, the annual awards and door prizes were announced and the closing session adjourned. After a quick trip to the MVAS' John Bryan State Park Observatory, one tired, but happy conventioneer returned to Oxford.

Dave Eicher is Editor of the **Deep Sky Monthly**, *a monthly magazine for deep-sky observers.*

Jack Roach's 6″ Newtonian.

THE PONCET MOUNTING

(with a difference — it's for low latitudes!)

All of the descriptions of the novel and utilitarian mounting designed by Adrien Poncet indicate that this mount loses its capability to function the closer one gets to the Earth's equator. This effect begins to occur at about 30° latitude. Although I now live and work in California at about 35° N latitude, I have spent a large portion of my life in Florida, all of which is below 30° N latitude, and it is my intention to return there some day. With this as motivation, I set out to design a mount using the Poncet concept which would still work at latitudes below 30°.

The problem is that the bearing surface must be perpendicular to the Earth's axis of rotation. The pair of low-friction pads tend to slide down the bearing surface if it is tipped toward the vertical, as it must be at low latitudes.

The solution is to somehow change to a bearing surface which is parallel to the Earth's axis of rotation. The pads will then not fall off as the Earth's axis becomes more nearly horizontal at the user's latitude. It turns out that the required surface is circular and is, in fact, the edge of the original surface used by Poncet. This is easily seen to be quite similar to the "horseshoe bearing" used in the 5-meter Hale and 4-meter Mayall telescopes.

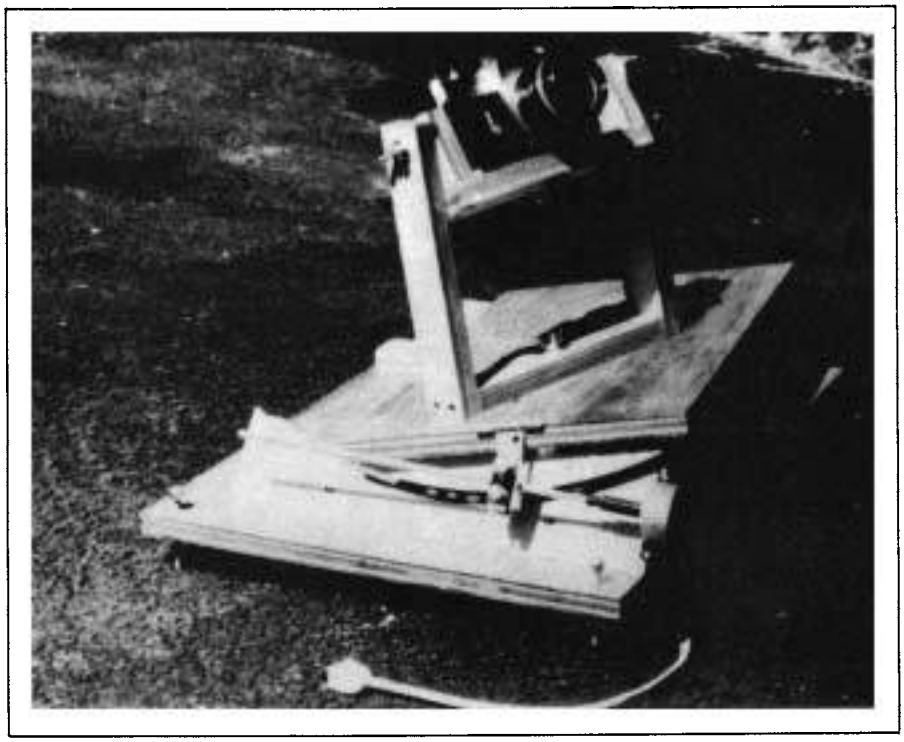
Before actually beginning construction, I made a full-scale drawing. This was necessary to determine the radius of the bearing surface as well as helping me to graphically envision the method of cutting the angles dictated by the latitude. In addition, I had to calculate the distance from the polar axis to the tangent arm drive since that I planned to employ a ½ r.p.m. motor and a ¼-20 threaded rod to drive the table.

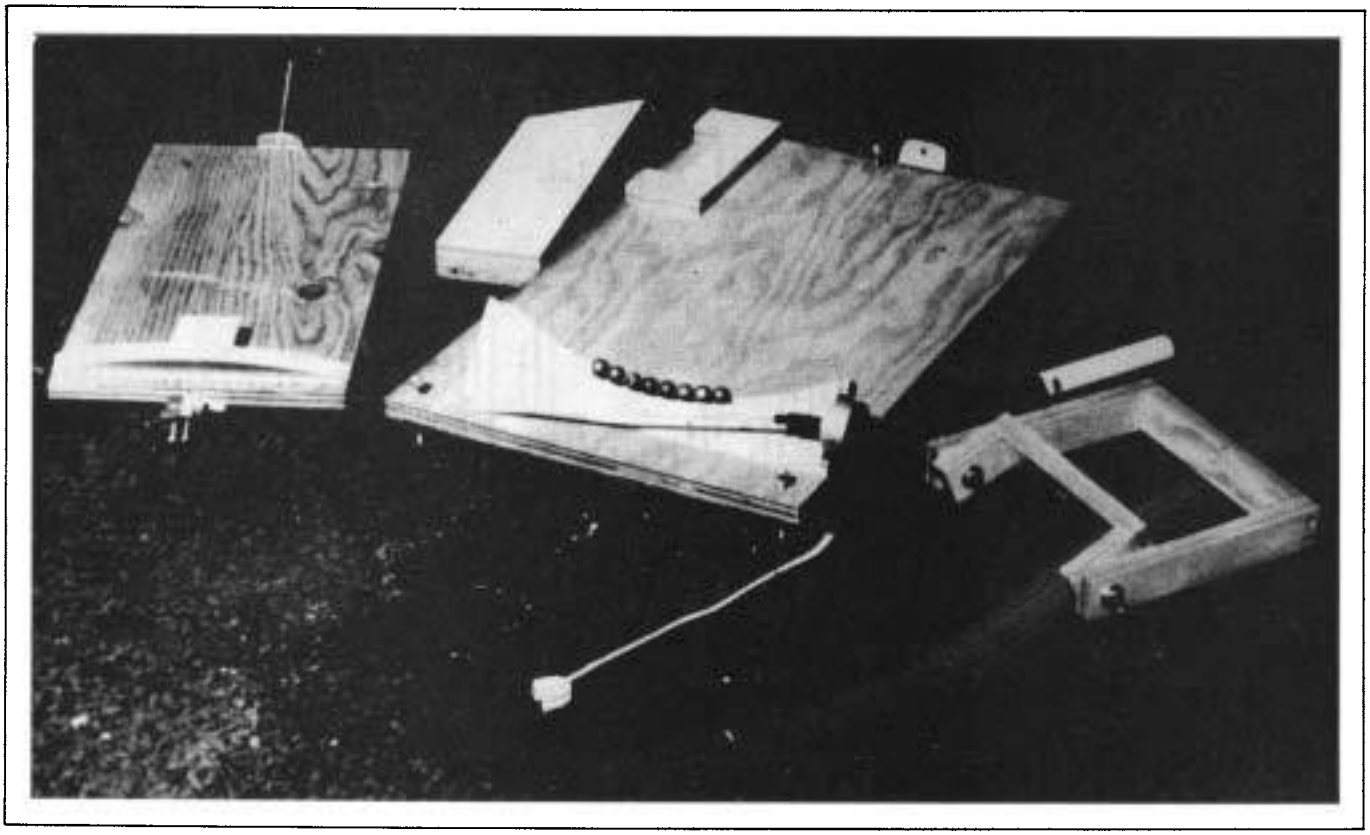
Construction began with the selection of a high quality laminate, a ¾" cabinet plywood. I cut a square groove of suitable arc length ⅝" deep into the paneling. The width of the groove was also ⅝". I used a router equipped with a trammel point to cut radii. Care was taken not to cut all the way through the wood since other saw cuts had to be made before separating the two pieces. After cutting the square groove, I made a second cut with a ⅛" router bit centered in the bottom of the groove, not quite deep enough to go all the way through the plywood. Later, when the two pieces finally were separated, each curved surface had a small lip. The ⅝" width and depth were chosen because ⅝"-diameter brass bearings were to be used to reduce friction.

Next I made the angle cuts to give proper tilt corresponding to latitude using a radial-arm saw with the blade tilted. These important cuts were made parallel to each other, with the plywood turned over for the second cut. Both cuts were made perpendicular to a line which bisected the circular groove. When this job was done, all the critical cuts had all been made.

The two parts were cut to width and then separated using a pocket knife. When assembled, the two parts with the circular cuts have the lip of one on the opposite side from the lip of the other. The fabrication of the remaining pieces is straightforward, as shown in the accompanying pictures.

Alignment of the mount is achieved using a small finder scope which is set parallel to the table rotational axis. This



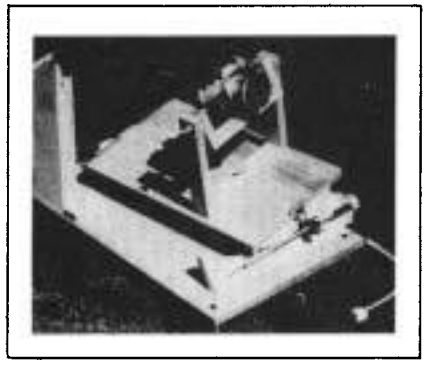


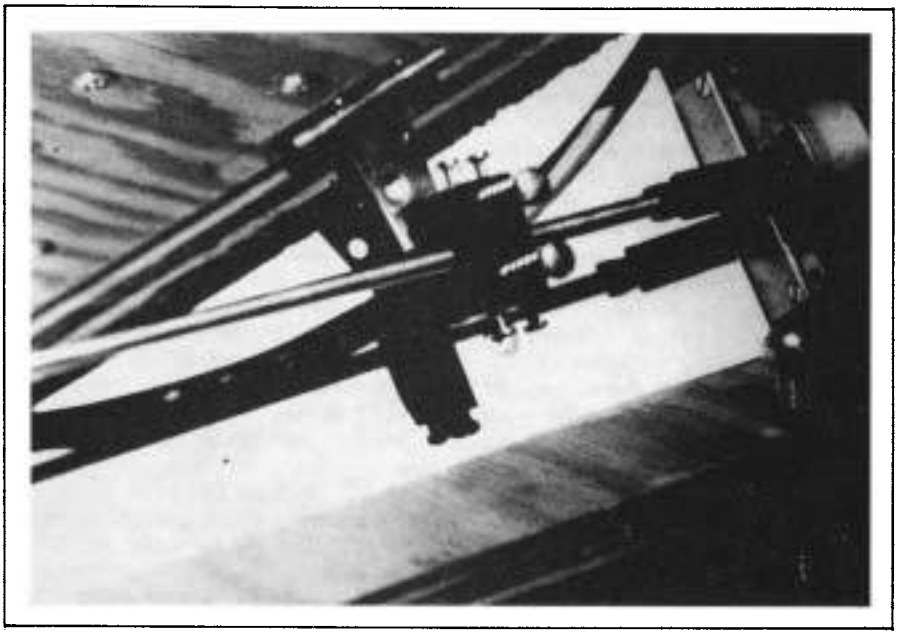
scope sits on a post cut to the appropriate angle on top and "vee" grooved parallel to its long dimension.

The drive screw can track for up to two hours. At the end of that time, it is reset using a split nut which was machined in the shop of a friend.

In a sense, this variation on the original Poncet design is complementary to the original in that the closer to the poles one gets, the less effective it becomes. However, at 35° N latitude, it still works well. Photographs taken at China Lake, California, show the Cygnus and Sagittarius regions of the Milky Way in perfectly tracked 5-minute exposures with a 50 mm f/1.8 lens. I used Ektachrome 200 force-processed to 400 ASA, and the pictures demonstrate that this mount can be compared with the best.

Richard W. Lasher
527A Nimitz Ave.
China Lake, CA 93555





The Macalester Four-Go
and the
RONCHI

I would like to offer a description of the Four Goal system presented to the Macalester College students for making a first telescope mirror. Whether you're making your own first mirror or you're engaged in teaching other people how to make mirrors, I hope you will find this useful. In either case, it's good because it's easier to learn and teach than the standard methods, and it's student-tested. What I'll present are four goals that you must try to achieve as you work the glass, but I want to begin with a few general principles.

General Principles

First, most of the work happens at the edge of the mirror — that's what Pi x r^2 really is telling us. Half of the area of the mirror is located in the outer 30% of the radius, and the other half inside that. Second, we're going to specify equal mirror and tool diameter. Using subdiameter tools is a whole new ball game, and isn't included in this discussion. Third, when you're working two disks, it is the upper disk that receives more attention in the central area than the outer parts. As a consequence, it will become hollow. The lower disk receives more attention on the outer area than it does at the central area, so it will go convex.

Goal One

The aim of this procedure is to prepare your mirror to focus light from infinity at some specified distance. This requires a procedure to hollow out the center of the mirror into a concavity of certain depth. What is necessary is an attack on that surface which will favor the center area being worn away faster than the outer area. This is achieved by grinding the mirror and tool together with the mirror on top (MOT) technique.

Using a long stroke hastens the central wear, but creates nonspherical surfaces (a curvature with the tool having a relatively flat center). Once the sagittal depth is achieved, a short stroke brings them into spherical contact.

Goal one is satisfied when the desired depth (called sagitta) is gained and a smooth spherical contact established between the tool and mirror surface.

Goal Two

This goal is to prepare the surface for polishing. This means maintaining contact between the tool and mirror surface while at the same time removing the coarser pits left by the previous grade of abrasive. This means an attack that wears the mirror surface evenly at all times rather than the strong preferential method created by MOT, the proper technique to accomplish goal one.

There is only one way this can be done, and that is to use the tool on top (TOT) of the mirror for no less than 50% of the time. While the "old timer" will immediately become concerned that this approach will go convex (after all that is what the tool did, isn't it?), what really happens is the concavity tends to go less concave (which is, of course, in the direction of convexity). But more important, the mirror edges get full attention and grind out the desired amount in less than half the total time usually assigned to each grade of grit. I advise using a 60-40 attack (60% TOT, 40% MOT) through grades 120, 220, and 320.

The slower attack offered by 400, 1000, and 2100 final grades allows the tool on top 100% of the time with no appreciable lengthening of radius of mirror. Careful examination of the new surface reveals that it will be done in less than half the time compared to "standard" techniques of MOT all the time.

Goal Three

We assume a mirror and tool fully fine-ground and ready for polishing. Goal three is concerned with obtaining a perfectly polished spherical surface. The

al System of Mirror Making

TEST

details on our lapmaking procedure with strong emphasis on subfaceting the main facets with nylon mesh material were presented in TM#1. Don't let it worry you that mesh subfaceting is never mentioned in the literature. Use it — it works every time.

Start immediately with the TOT method. This will attack the edge of the mirror so that it will polish ahead of the center area. My experience of being able to see a Ronchi line pattern well enough to test a mirror after only 50 strokes of polishing (about one minute of work!) reveals two items of interest: 1) the test allows it to be seen as the pitch lap used is very efficient and 2) we always find straight line patterns immediately, which shows a nonpreferential attack to the mirror surface. It does not turn down the edge. It simply polishes out the edge.

Continue polishing with TOT. Gradually, the center polish develops along with the edge. We don't use MOT, which was very successful in goal one's needs, because we are no longer trying to deepen the center.

What will happen is that the center — being less efficiently polished, which is really a wearing away process — will be seen to go high. An oblate spheroid will gradually result. Do not be concerned, it simply means the edge of the mirror is getting the attention it deserves and the total polishing time, instead of taking the ten hours usually expected, will be done in half the time.

Well, you ask, what do you do about that high center?

While that may seem like a good question, it only means you didn't do your homework earlier in the game. What does MOT do? It wears the center of the mirror faster than the edge, of course. But that's the next step.

Use a properly set up Ronchi tester. It's quick, and won't confuse you anywhere near as much as the Foucault test. More on that later.

Goal Four

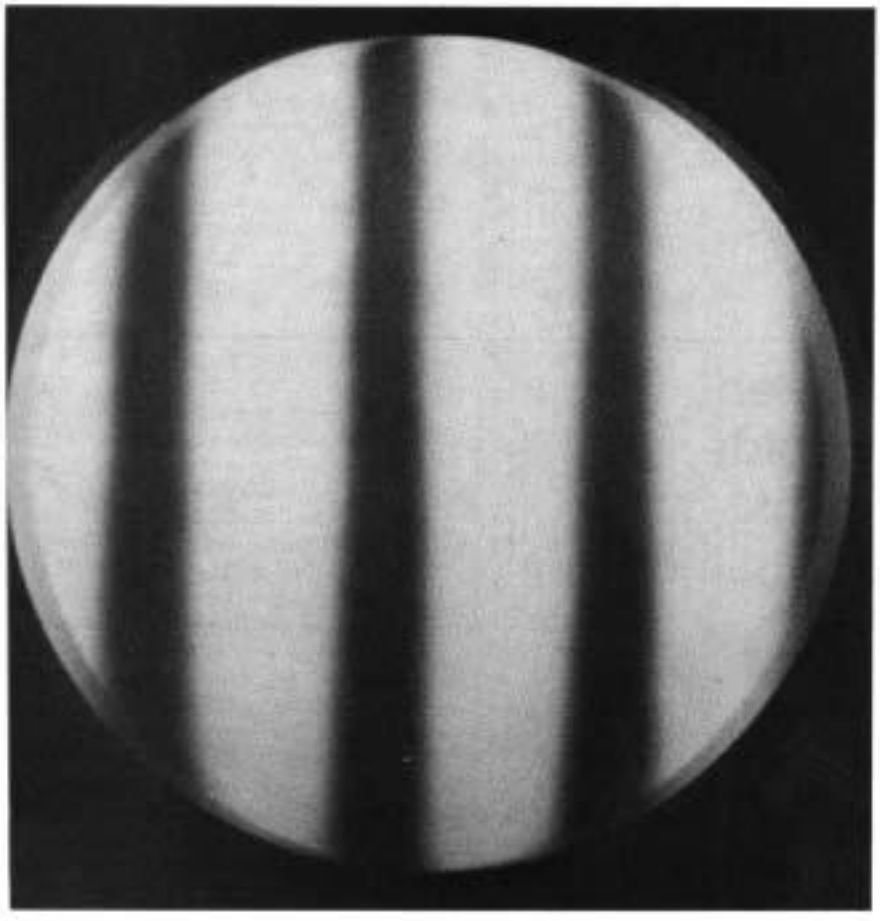
The final goal is to obtain the proper surface of correction, a paraboloid.

You must start with your polished sphere. Because the center of the mirror needs slight deepening, MOT is demanded. But no tricky lap treatments, please: you should have routinely refreshed the mesh pattern and maybe the main facet pattern every now and then. When you're ready to polish in the paraboloid, the lap should still be in good shape, because you've maintained it (well, haven't you?).

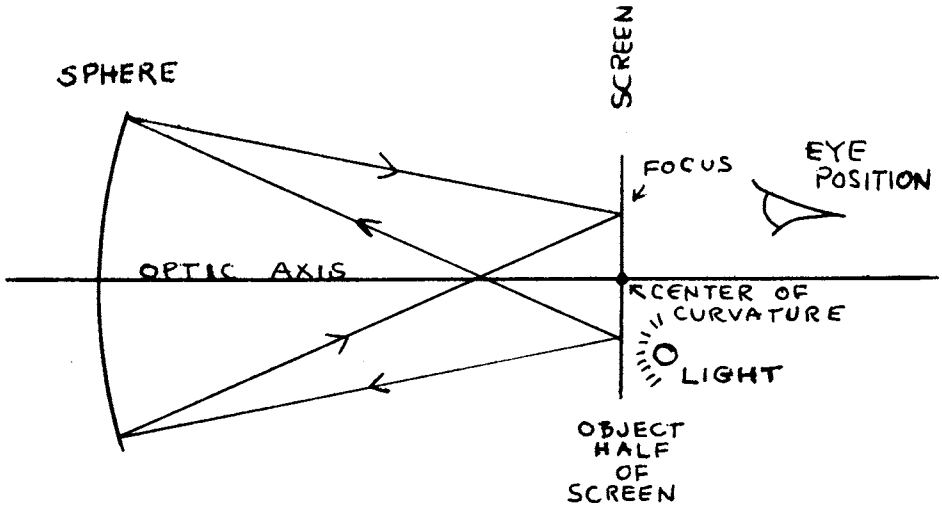
Start correcting with a fresh lap (not a new one, an old one resurfaced). Use a firm, long, deliberate stroke with an overhang about 1/3 the mirror diameter. Don't hurry it. Don't rush it. Be firm but not heavy-handed. Polish for 200 strokes.

Only 200 strokes.

Retest and see if the straight lines you should have had at the end of goal three are now starting to belly out slightly



Screen at center of curvature of a spherical mirror



(screen inside center of curvature) and pinch in a small amount when "outside of focus." If not, not to worry. At least you are not being too vigorous and hollowing out the center too rapidly, creating a hole in the center. Just be judicious in your attack, no more than 200 strokes at one spell. Test frequently (very easy with Ronchi, of course) until the developing curvature of the lines satisfies correction estimates.

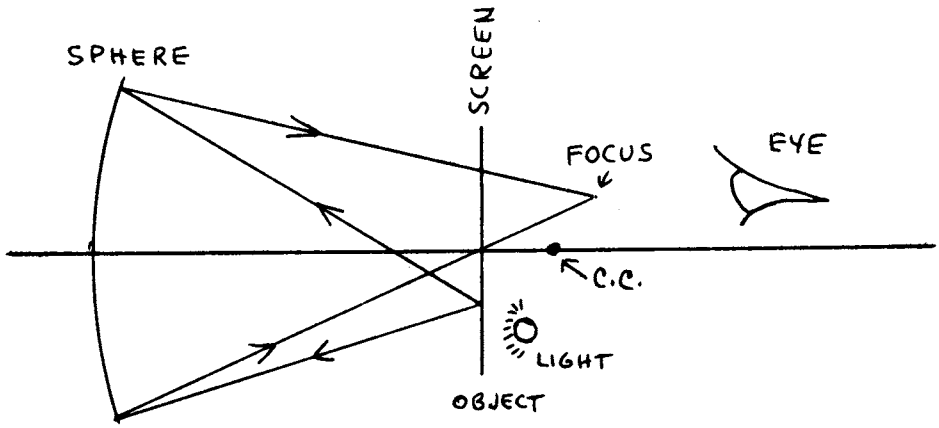
The old idea that an overcorrected surface was somehow fatal, called in ATM books the "fatal hyperbola," is in the mind only. To control a hyperbola, return to TOT for a short time and the overly deep center will respond as the edge assumes a deeper curvature again.

Using the Ronchi test as we do at Macalester is a quick and accurate way to test a paraboloid. Your concern about what constitutes a "proper degree" of line curvature is fully recognized. The best way is to look at other mirrors that are considered better than 1/4 wave optics, maybe commercial optics (although I could tell you a few stories about that subject) to see how very little from straight line patterns the bands are with an f/8 mirror. The album of appropriate line patterns for mirrors for varying diameters and f/ratios using a standard 85 to 100 line screen, though not entirely complete, will probably be of immense help.

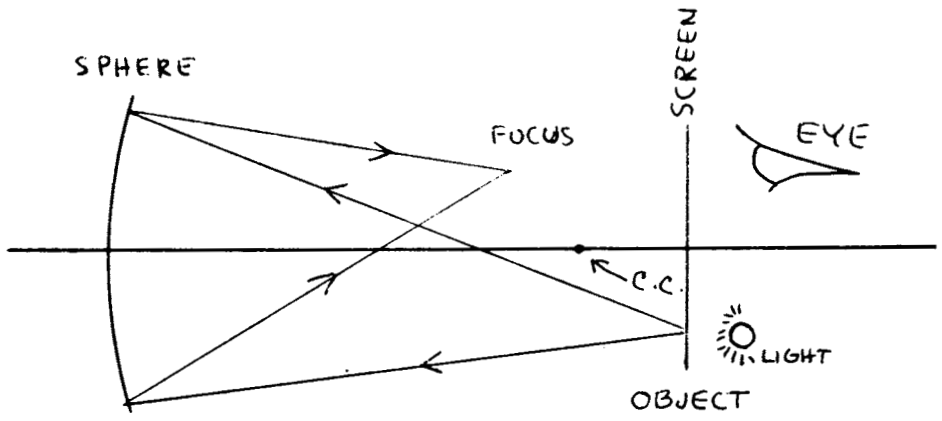
The coarse optical transmission grating that has come to be known as the Ronchi screen, is an easy and quick way to test telescope mirrors. Although its application in this context is not the same proposed by Vasco Ronchi in his early experiments (which is why I hesitate calling this a *true* Ronchi test system), it has been carried down through the years as a form of Ronchi test.

My correspondence with mirror makers around the world has shown me the extremely high esteem telescope makers feel for standard Foucault methods. If some of the methods presented here appear to you at first blush to be in conflict with this time-honored method, it's time to open your mind a bit. Once you've acquired the experience to properly utilize the system of Foucault, you tend to forget the problems you had with it at first. The intricacies and difficulties of properly setting up the test and interpreting the knife-edge observations has probably been the single most important reason amateur telescope makers have given up on their initial mirror making attempts. Remember guys, it's a procedure sufficiently difficult to understand, let alone fully comprehend that the enthusiasm you bring to grinding and polishing a mirror can soon fade out. Well, enough of that — we all had a few good bumps learning to walk. Let's not

Screen outside focus



Screen inside focus



forget the hardships in the exultation of success.

"Well okay, how can a Ronchi test help me?" you're probably asking. I'll try to list the advantages. First is its ease of interpretation. This in turn acts to establish confidence — understanding of the condition of the surface. Getting mired down looking at a number salad of zonal readings and trying to figure out what your next correction procedure should be just isn't confidence inspiring.

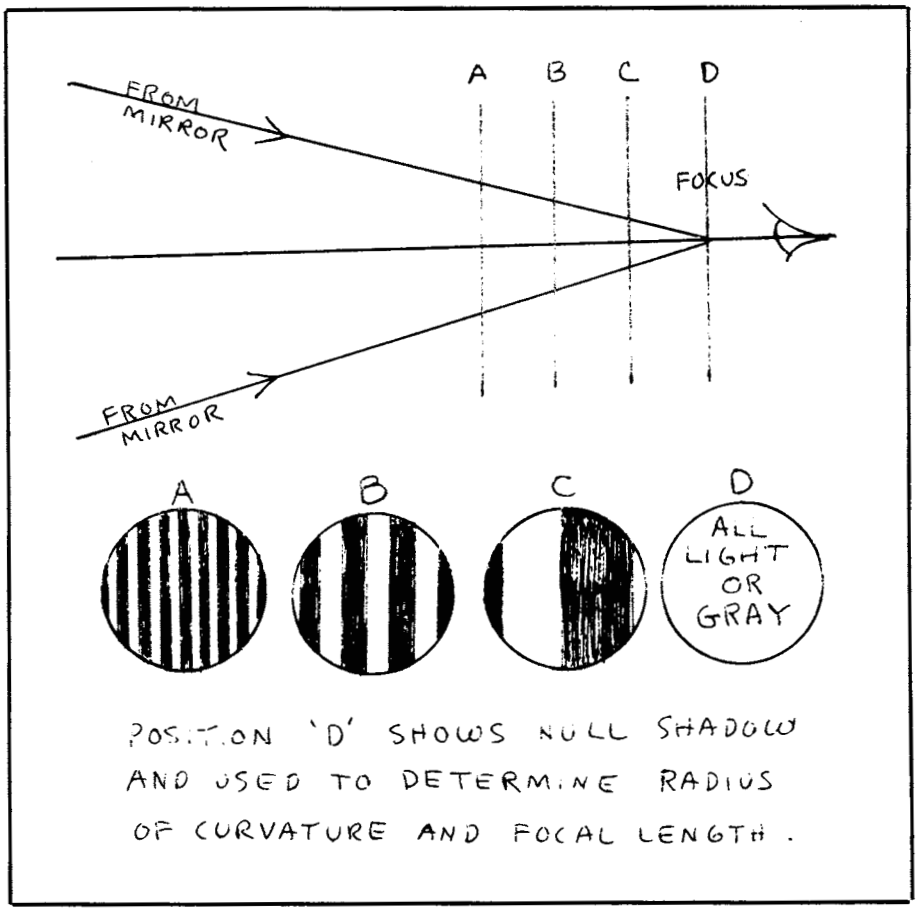
Second: Especially for people like me who teach others mirror making (to adults and college students alike; in fact, over the years to the tune of something now in excess of 275 successful telescopes), it's nice to see your students not give up. Now, I'll make no pretense that each and every telescope is still being actively used, but never having a single failure of completion must speak for something being done right.

Third — but first another digression. (I appreciate some of the following may not be taken too well at first glance by the old-timer telescope maker. For that I am truly sorry. But having made my first mirror in the 1935 era from a John M. Pierce kit, it is entirely possible even I too may be considered an old-timer. Maybe 44 years of high interest and exploration of testing techinques isn't enough. It might not be in the minds of some who started this great activity in the 20s, but it's the best I could manage.)

And third, the Ronchi test is sensitive enough to permit accurate testing. What is not recognized by the Foucault test user is that the testing is based on the shape of the lines produced. They are not to be interpreted the same way as the Foucault test. It is the old apples and oranges comparison mistake.

But every little nuance of irregularity of a deviant surface is seen (and far more easily understood) by the shape of the lines produced by that irregularity. No numbers are involved, just recognition of curvature deviant from what is desired and action to remedy taken. You don't need to know the magnitude of a problem to correct it — you just correct it. A drowning person doesn't need to know how deep the water is — once it's over his head. He needs to know how to swim.

Fourth advantage: You just work until the line shape is right. And how do you know that? You learn the proper line shape pattern for a well-corrected mirror in the same way you learn anything else. By working at it. You examine other mirrors, especially those proclaimed as good ones, made by Foucault testing and tested on the ultimate test, the stars, and from them you determine what the Ronchi line pattern degree of curvature happens to be. Each diameter and f/ratio will differ, of course, but so too do the numbers for Foucault correction.



Advantage five: Ronchi makes it easier to tell turned-down edges from other kinds of problems near the edge. Used as it should be used, you shift the screen position inside and outside of the neutral center of curvature position. Turned edges are caught very early in the game, so remedial methods will cure turned edge very early. You don't need to distinguish between the bright diffraction edge and the bright edge of a TDE.

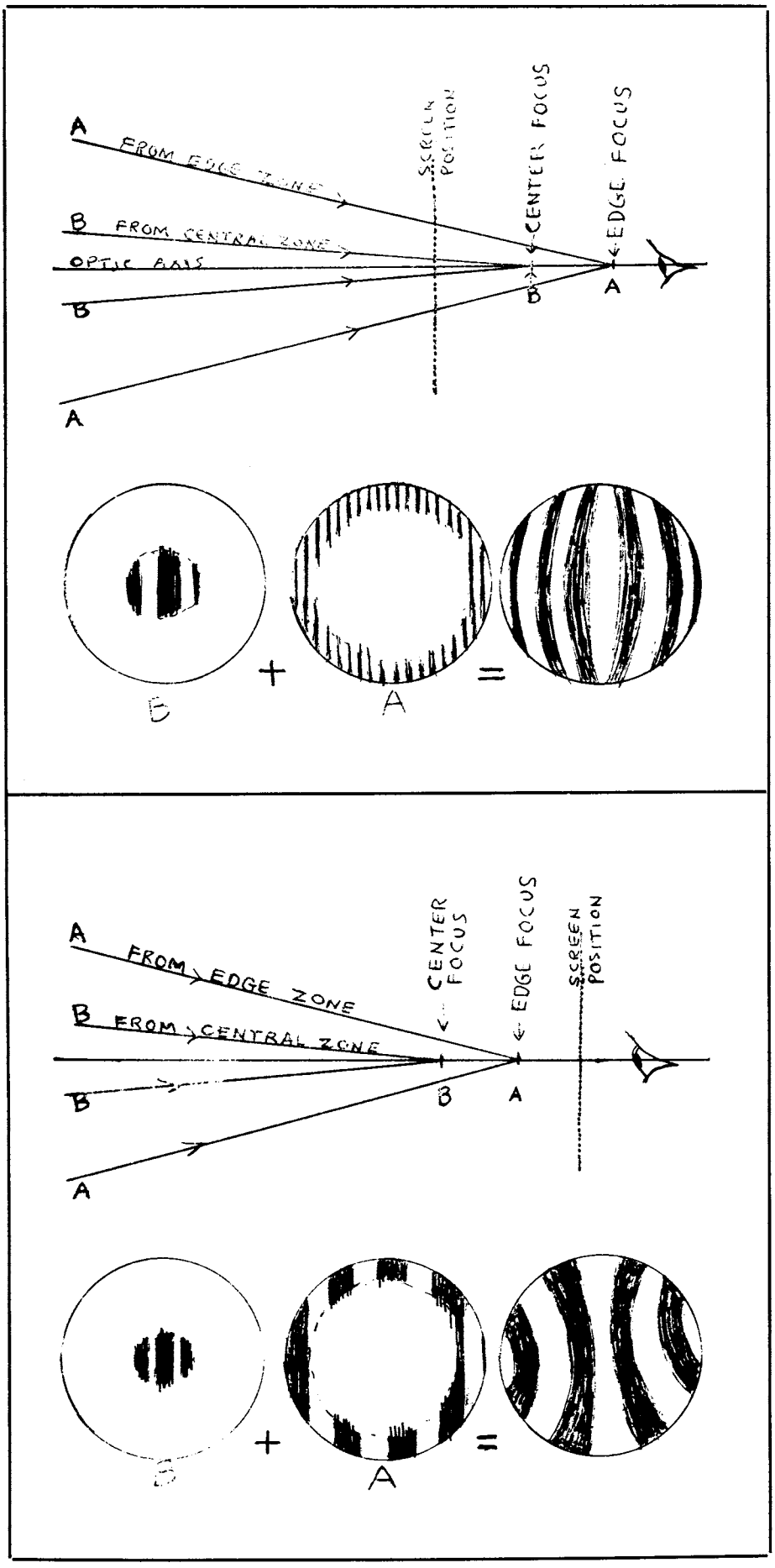
Here's a sample of how it works: This past January I had the students take part in an experiment to see just how little we had to polish the mirror before a readable line pattern could be obtained. The first student went 500 strokes, by count, into his polishing routine. He had such a bright line pattern the next student was asked to test after 200 strokes. Same thing — we easily saw the line pattern. It then occurred to me to work the other way, so I asked the third to polish but 50 strokes after the lap was formed and he did so. You could see the line pattern clearly revealing the nature of the entire surface curvature at the earliest possible point in time. Not only could a line pattern be seen, but it was also straight.

In addition to the above, I asked three more students to polish with the classical mirror on top of tool (MOT) procedure for the same 50 strokes. The center third was polished enough to show lines, but they weren't straight. Their curvature indicated a new radius forming at the center that was shorter than the edge area, the start of a turned-down edge as the natural result of MOT polishing.

Sixth advantage (and maybe the greatest): It allows the student to immediately recognize the overall condition of the surface curvature relative to a sphere. Once able to recognize a problem, if one exists, he can initiate procedures early in the game which will not only eliminate the immediate problem but continue to work in his favor until the next stage of the total work is accomplished.

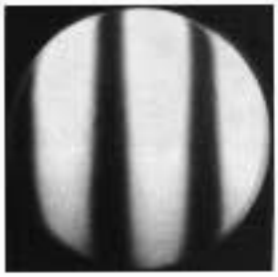
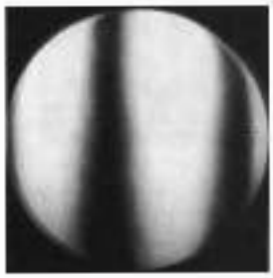
Seventh advantage: The test image is bright. I submit to you testing is no fun done in the dark. The copious light coming through the bottom half of the Ronchi screen allows testing in normal room light conditions (which, in a class, does not interrupt the work of others). Each mirror maker can set up the device instantly for his personal radius of curvature with a simple repositioning of the test stand. The target is bright, and therefore easy to determine, understand, and correct.

Sherman Schultz
Macalester College
Physics and Astronomy
Saint Paul, MN 55105



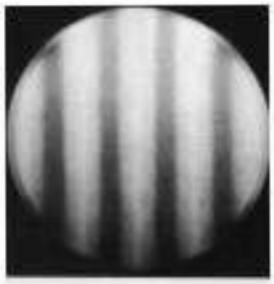
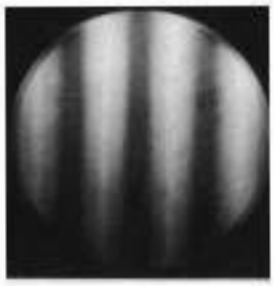
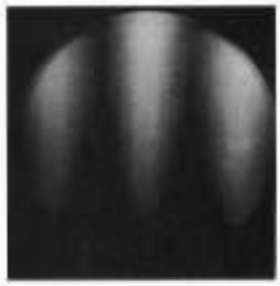
A RONCHI ALBUM

8" f/8 SPHERE

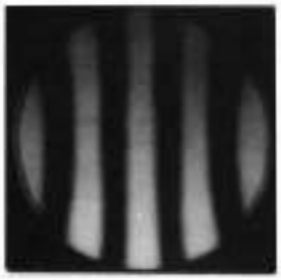
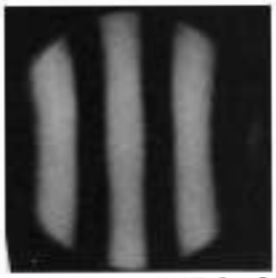
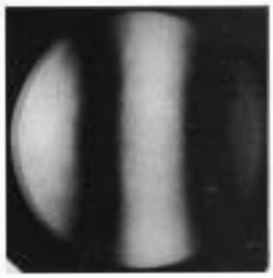



OUTSIDE THE RADIUS POINT

INSIDE THE RADIUS POINT

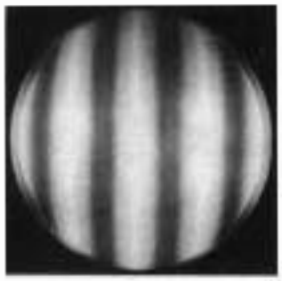




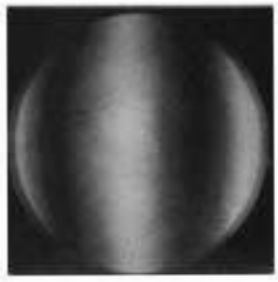
8" f/8 PARABOLOID

OUTSIDE THE RADIUS POINT

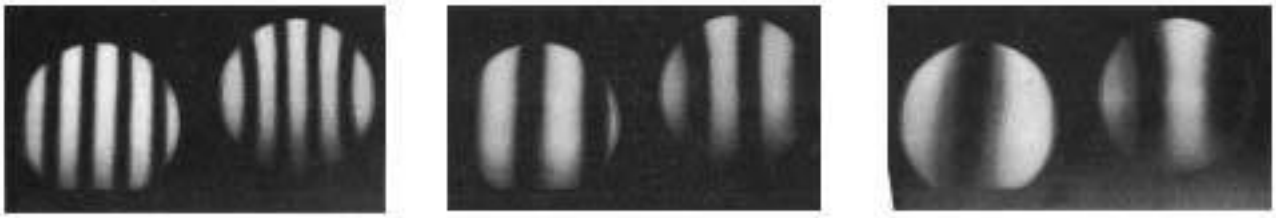
INSIDE THE RADIUS POINT





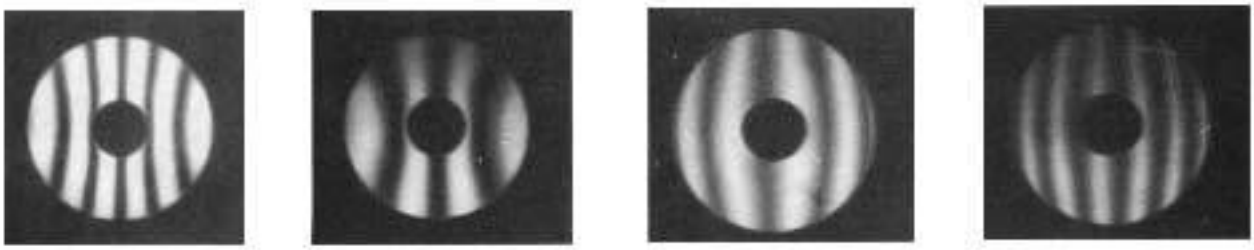
A RONCHI ALBUM

A SPHERE AND PARABOLOID COMPARED



both are 8" f/8 mirrors (outside R)

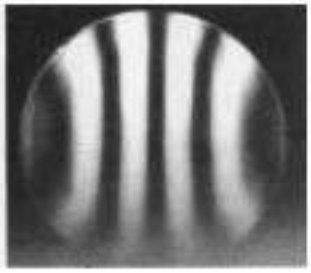
A FAST PARABOLOID



OUTSIDE INSIDE

the 8" f/4 primary of a Cassegrain

A 6" f/4

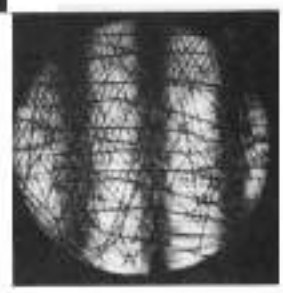


OUTSIDE

INSIDE

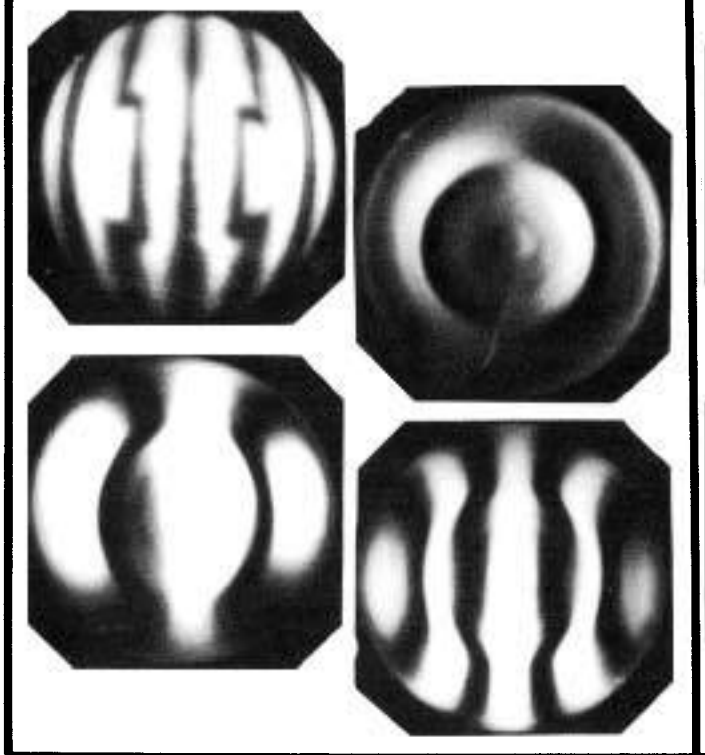
DEFECTS

CHIPPED

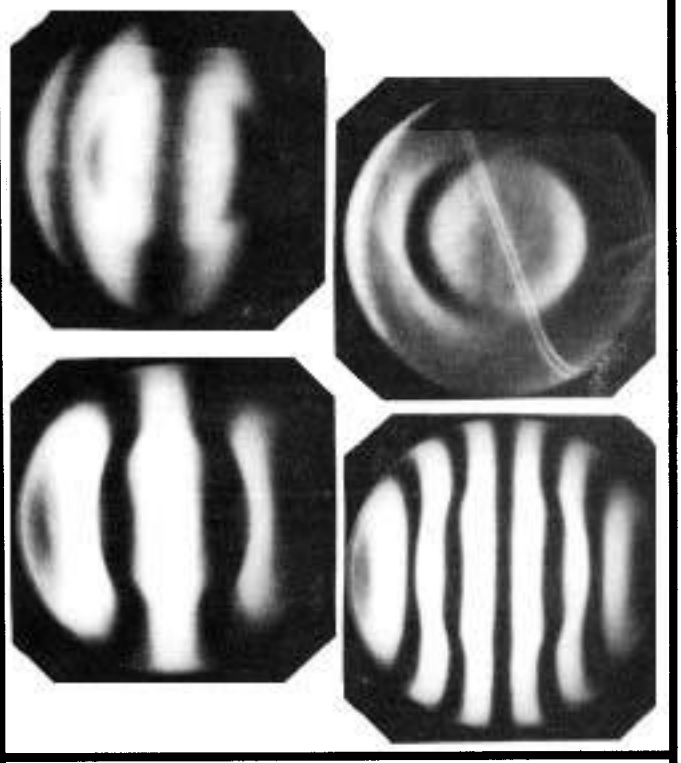


EXPERIMENT SCRATCHED

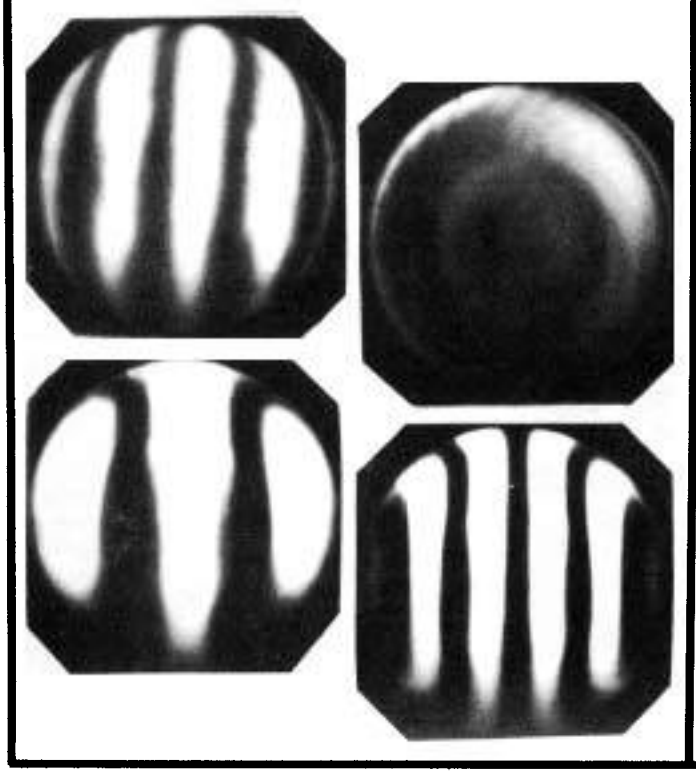
CASE HISTORY: 12" f/4 SPHERE



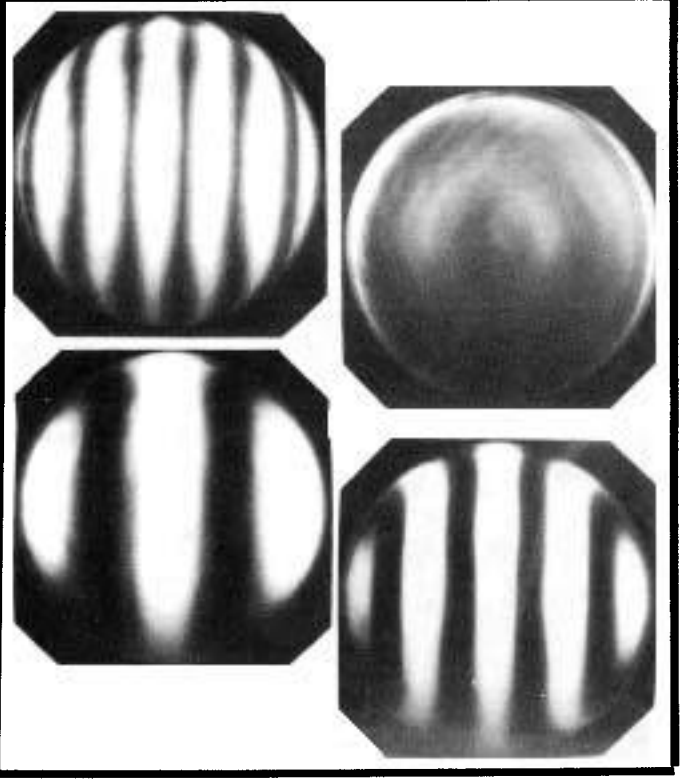
1. AFTER POLISHING



2. 10 MINUTES OF CORRECTION



3. 15 MINUTES MORE



4. 35 MINUTES MORE

A Classic, Good-Looking Observatory and Dome

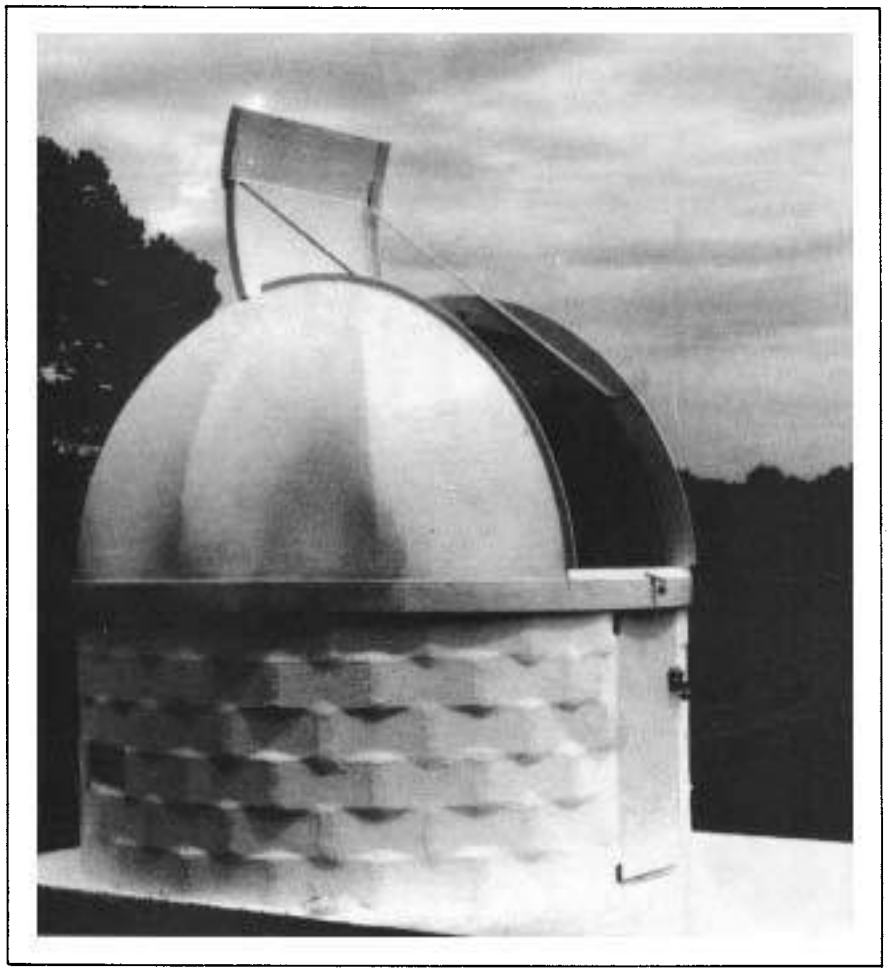
that turns on golf balls

An affirmative reply was the last thing I expected when I approached school officials about buying a telescope for the Physics Department, and when the Student Council agreed to finance the project, we started making plans. The instrument purchased was a Meade 8-inch Newtonian with all accessories for photographic as well as visual observational use.

It didn't take long — one night, in fact — for us to realize that we had two problems: 1) the lack of portability seriously dampened spirits and resulted in too much wasted time achieving proper alignment for photography; and 2) the amount of lighting present around our high school virtually limited us to observing sun spots.

An observatory seemed to be the answer. Factory-built domes were too expensive, but we wanted that traditional look. The solution was to build our own from the ground up.

The completed structure



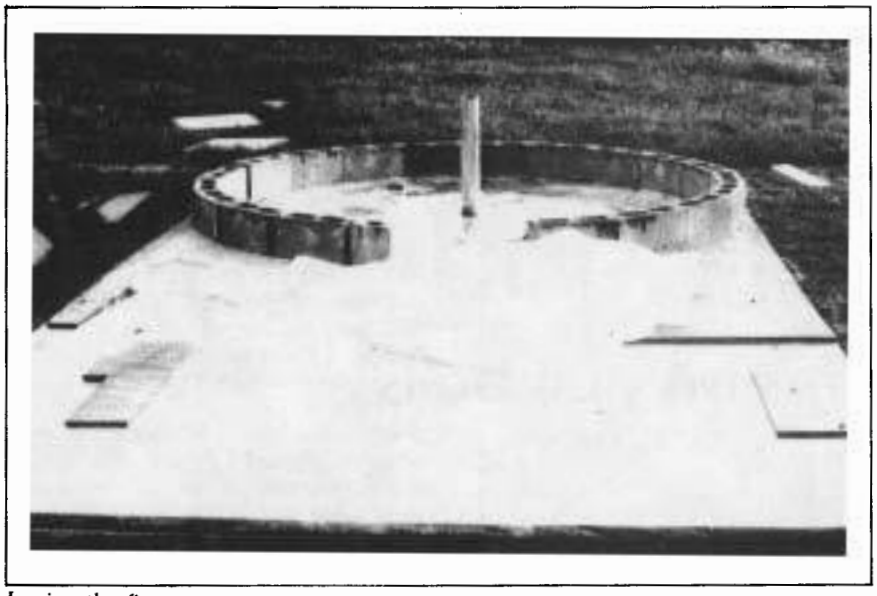
I'm experienced in woodworking but had never worked masonry or fiberglass before. However, the most difficult part was deciding to go ahead and do it. The only outside help we had on the entire project was in pouring the slab and lifting the finished dome onto the base. Two or three people working together could build the complete observatory in a week for a total cost of less than $1,000. It could be built for less — but I really "beefed up" the dome with fiberglass and that stuff is expensive.

The structure is very solid, completely weatherproof, comfortable, functional and will last a lifetime with little maintenance.

The ideas for the rib structure in the dome and the golf ball rotation system came (with some changes) from Astronomical Telescopes & Observatories for Amateurs by Patrick Moore. This book has many good ideas in it and is interesting reading even if you don't plan to build your own observatory. My senior physics class deserves thanks for "finding" 120 golf balls.

Having decided on an outside diameter of ten feet, we began construction by pouring a 10′ x 20′ slab, properly reinforced, around the permanent pier. The pier is set to a depth of 3′ in concrete and is also filled with concrete to within about 4″ of the top. Machining of the pier (aluminum irrigation pipe) was done beforehand, as was burying the electrical wiring to the scope drive. Building the structure flush with one end of the slab left a 10′ x 10′ concreted area available outside for observing meteor showers, etc.

After drying 24, hours the slab was solid enough to start work, but we were advised to leave a plastic cover over



Laying the first course

everything for about a week to insure proper curing. (This applies to the hot humid Arkansas summers; ask a builder in your area for curing time. Anyway...) With the slab poured and the pier plumbed and centered in one 10′ x 10′ half, tie a crayon to one end of a string and tie the other end in a large loop to slip over the pier. Adjust the string so that the crayon reaches nearly to the side of the slab (about 5′). Using the string as a radius, walk around the slab marking a 10′ circle to serve as a guide for the first row of blocks.

Set each block (use half blocks at the door) so that the outside corners just touch your line. This means that there will be a large gap between blocks on the outside (inside blocks should touch) and also an overhang with each subsequent layer. These gaps and overhangs can be neatly filled with mortar. (Remember, I'd never used mortar before, either!) Fill any gaps and overhangs inside as you proceed.

NOTE: Subsequent layers of blocks were kept lined up vertically by merely "eyeballing" down the outside to the block beneath it. Also check each block with a level as you proceed. The top is all that has to be level, but the care you take now will result in a stronger, neater appearance and less adjusting with the top row. I also installed two thermostatically controlled vents to help control temperature and moisture.

The base was made 4′ high for our scope but you might have to alter it some for your needs. No reinforcing is required in the walls since the circular shape is self-reinforcing. When the top tier has been finished, stuff old newspapers into the holes in the blocks and fill them with mortar; this will keep any moisture and insects out. Install anchor bolts about every 2′ in the holes with mortar, leaving 1″ above the blocks.

The roller track is made of two layers of ¾″ exterior plywood (as are all structural parts), cut 6″ wide. Cut enough arcs of this size (10′ outside radius) to make four complete circles. Two are used for the top of the building, the other two for a double layer base plate for the dome. All of the plywood pieces were marked using a length of 1 x 2 for a compass. Pivot it on a nail and use a pencil pushed through different holes at different distances from the pivot for different radii. Mark the outer line with the pencil 5′ from the pivot, then move the pencil 6″ back toward the pivot and mark another arc with a radius of 4′6″.

I cut each piece out with a jig saw (slow work in ¾ wood, but much easier than with my band saw). You now have an arc 6″ wide with an outside radius of 5′ and of whatever length you can cut from a sheet of plywood. Several pieces must be cut and placed end to end to form a complete circle. Bolt one completely down to the anchor bolts. Next, glue the second set of arcs, and nail it to the first circle with resin-coated nails. NOTE: Nail only along the inside and outside 2 inches; the center must be free of obstructions for the golf balls to roll smoothly. Also, some cutting or drilling — but NOT all the way through — must be done on the underside of the top layer to provide clearance over the anchor bolts.

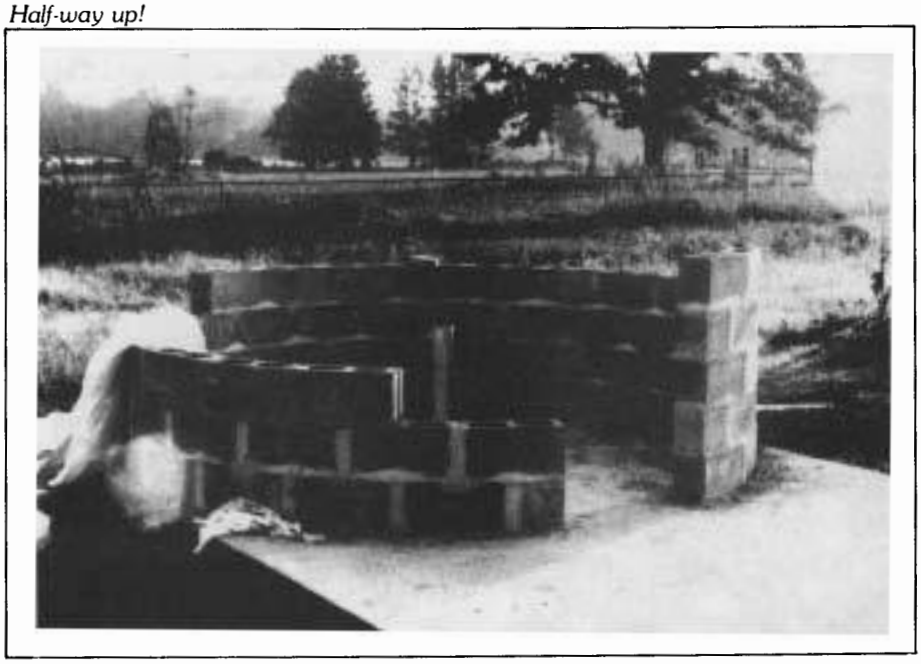
Be sure, when placing the second layer of arcs, to stagger the joints with those of the first layer. When the plate is in place, coat it well with a urethane finish or fiberglass resin.

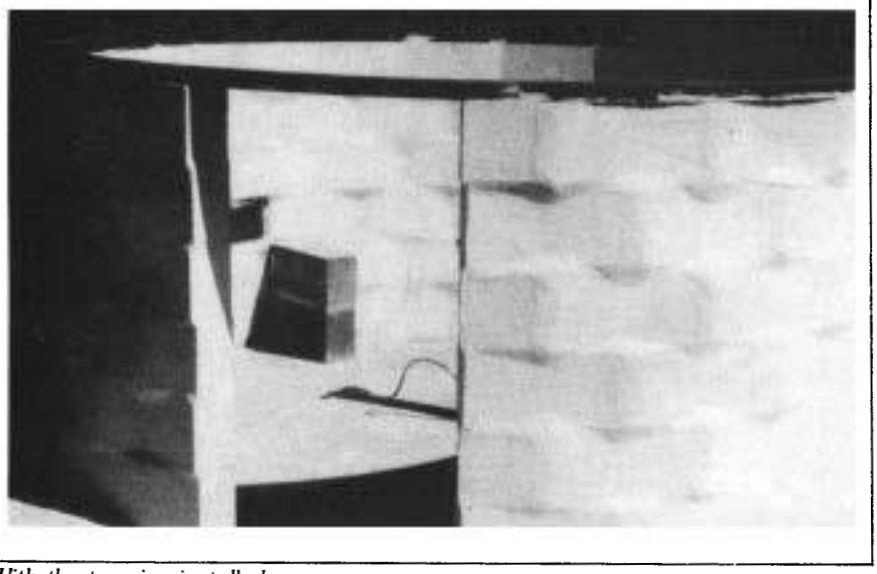
The track for the golf balls is made from a strip of interior house trim plastic molding. It is just the right width and will take on a perfect curvature to keep the balls rolling smoothly. It comes in 8′ lengths. Simply tack the strips from the inside to blocks; then nail the blocks down to the base plate. Be as accurate as you can, but some play doesn't seem to hurt anything.

Small heavy-duty drawer rollers were nailed into the outside of the plate. These are spaced about 18″-24″ apart and can be adjusted to remove play in the rotating dome and to insure that the dome doesn't rub the sides. These run against the dome's 4″-deep skirt which hangs down just a little below the base plate. The idea of this was mostly weatherproofing.

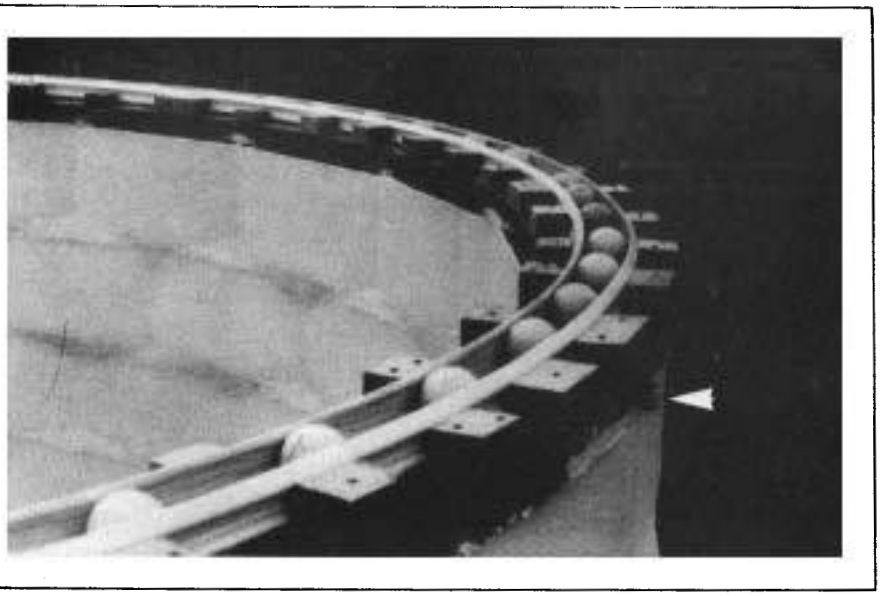
Frame in the door in 2 X 6s and fill any gaps around the framing with mortar. (There will be rather large gaps if the door frame is to be parallel.) Install a

Half-way up!

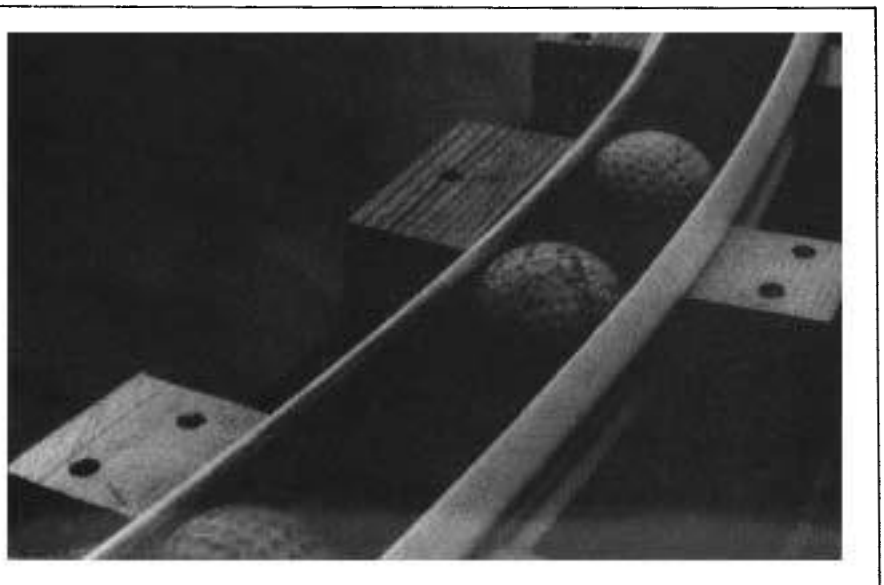




With the top ring installed.



Golf ball bearings! Note the roller above.



metal threshold and the door of your choice. We used a sawed-off closet door thoroughly sealed with urethane. Two good coats of white concrete block waterproofing compound inside and out will really give the concrete building a finished appearance.

Begin dome construction by nailing together the second set of 6"-wide base plate circles which were cut out earlier. Again, be sure to stagger the joints of the two layers. If you use 1 ¼" resin-coated nails from the top side, there will be no bumps on the lower side. Remember, the lower side must be smooth to run on the golf balls.

When the base is assembled, level it very carefully using shims if necessary. If this upper plate is not parallel to the lower plate on the concrete block base structure, the balls will not function properly.

Next assemble the two main ribs of the dome which run from front to back. These ribs were cut to an outside radius of 4'3" since they do not pass through the center of the sphere. (For your own observatory, remember that this radius depends on the width of the door. Ours is 36".) Each main rib is two layers thick; the inside layer is 6" wide from the front to the top cross piece. Cut only 4" wide the rest of the way down to the back. The outside layer is 4" wide from end to end. The 4"-wide outer layer provides for fastening the dome skin and the 6"-wide inner section is the lip over which the door will fit. The cross brace further serves as point of attachment for the upper door section. The upper door is hinged whereas the lower door lifts off.

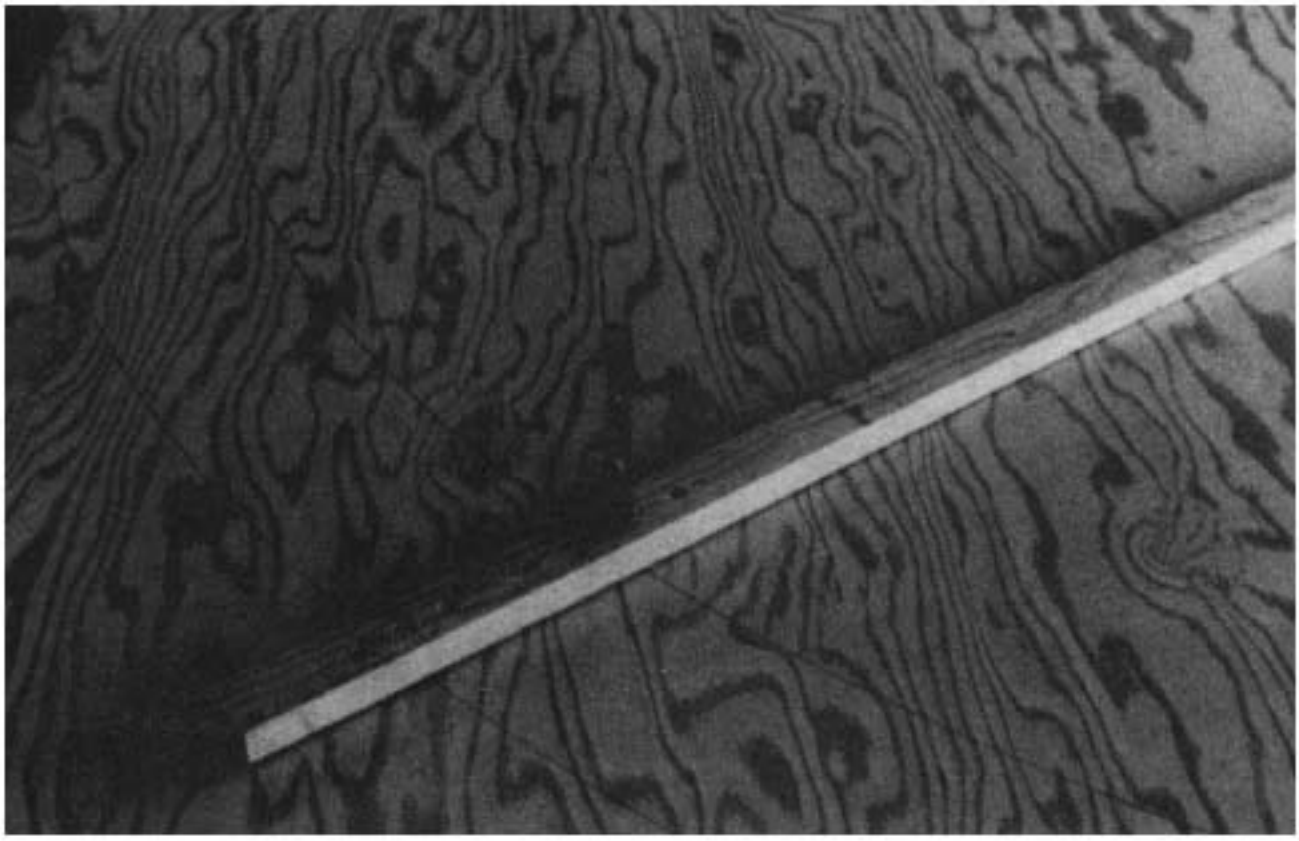
The other ribs are cut to a 5" outside radius and are attached at both ends with angle brackets.

The most tedious part of the whole project was putting on the skin panels of ⅜" exterior plywood. Since it is nearly impossible to measure accurately and allow for the curvature, I used cardboard templates for each piece, then transferred its shape to the wood.

Plywoods are not meant to bend, and when they do, they tend to bend in only one direction — across the grain direction of its face. Making it conform to two curvatures at the same time was accomplished by sawing kerfs across the grain on the inside face. These kerfs were about ¼" deep. Be careful not to cut through; check the cut depth on a scrap first. Use resin-coated nails to apply the panels and glue if you have three hands.

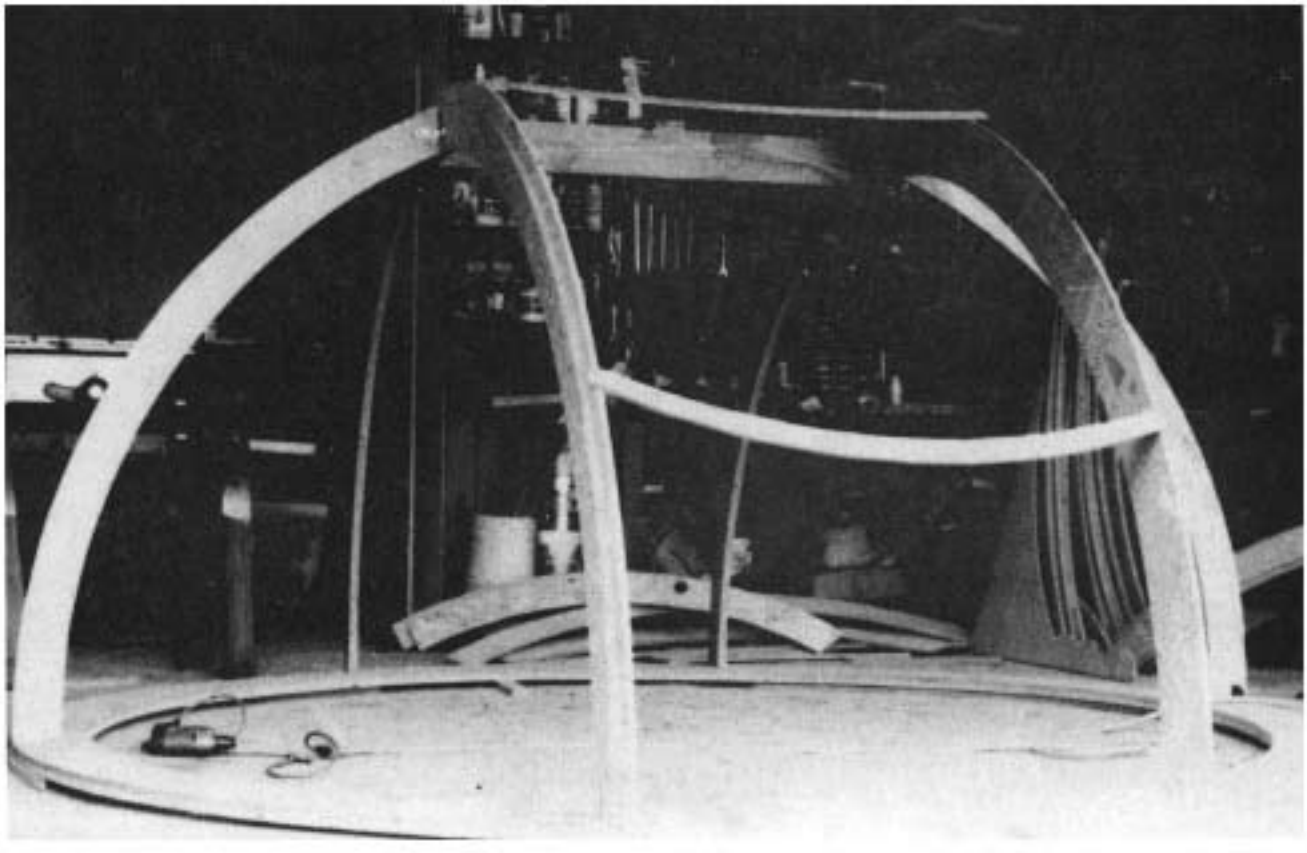
Next, a 4"-wide skirt is added around the base. You must raise the whole structure up on blocks to do this. I added another piece at the bottom of the door opening tilted down at the front to facilitate drainage of any wind-blown rain that might get under the door.

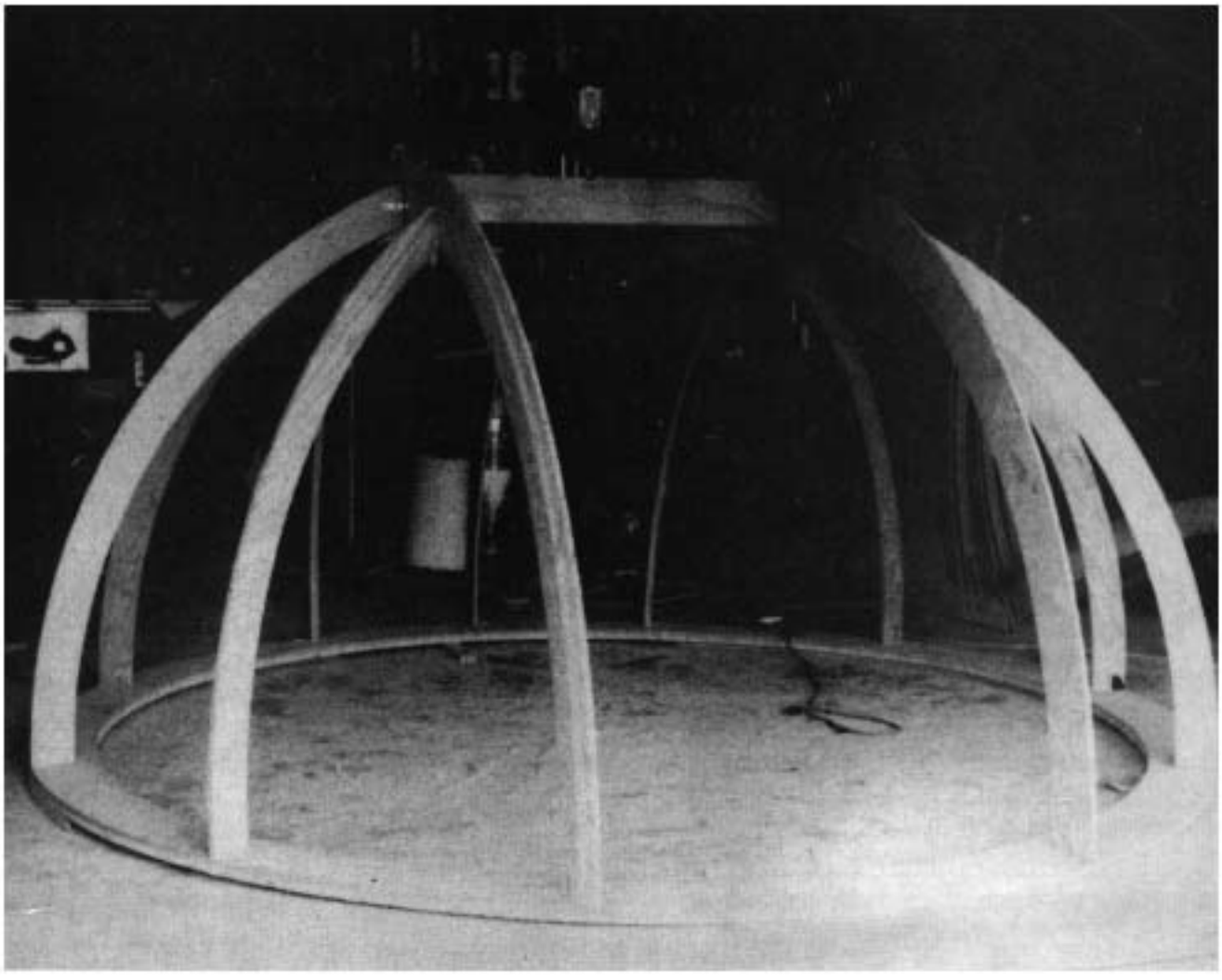
After all the panels and skirt were on



Jig for marking a long radius.

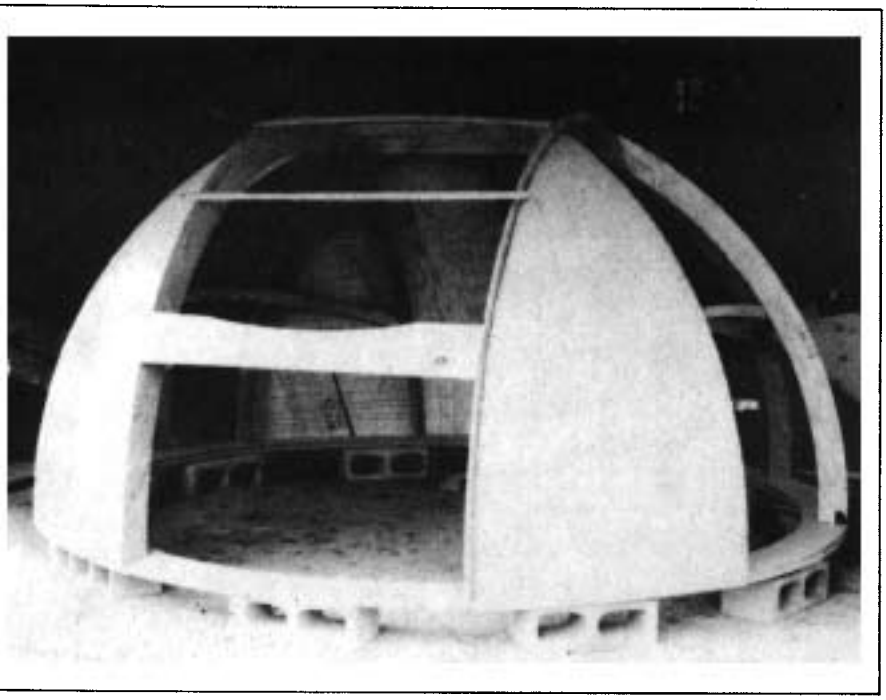
Beginning the assembly of the dome.





All the ribs in place.

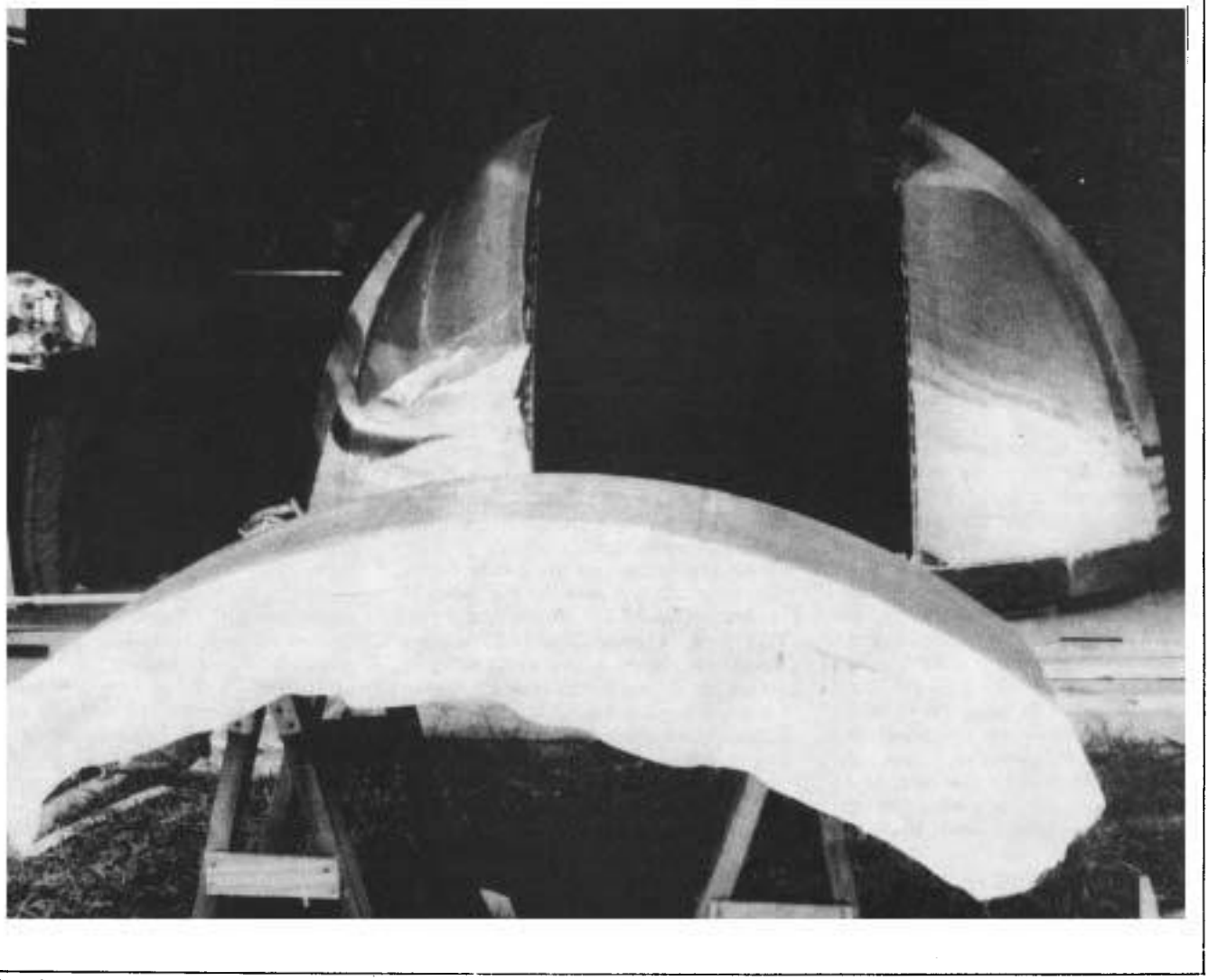
Covering the frame. Note brace in the slot.



and secured, the first two layers of glass cloth and resin were applied. I put on a total of three layers of cloth and about three extra coats of resin to smooth it out. The skirt is also covered with fiberglass.

The lower door section came next. It is made of three ribs of the same radius as the dome main ribs and 2" wide, with a cross piece at each end and is covered with ⅜" plywood. It is very light and strong. The upper door, which is hinged to the dome, is the same except that it is shorter and flared at the lower end to overlap the lower door when it is closed. The upper door stays open during overhead observations by means of two 6' aluminum shelf standards which also lock it shut.

Add a screen door hook to each side of the lower door and hasp lock at the bottom and the structure is complete. Top it off with several coats of a good marine enamel and invite your friends over to help you set the dome on its base. Even through the estimated weight is



Fiberglassing the dome and lower "door".

about 300 pounds, it rotates with one finger.

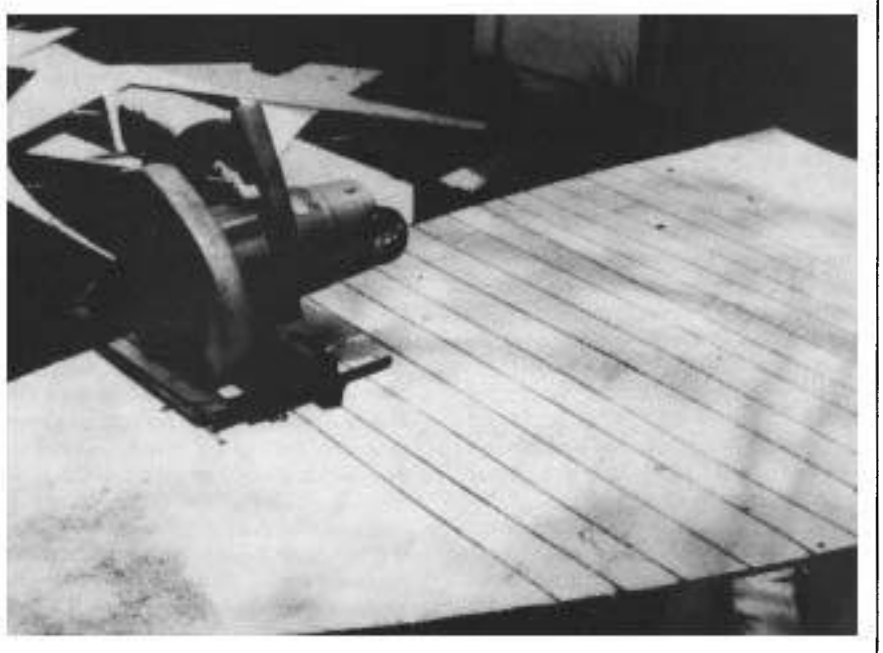
Some other features added were: built-in seat with storage for a step platform, tie-down bolts for very rough weather, and darkroom safe light. There is also a white light with switches which, along with wiring, is all surface mounted on the base section, of course.

The inside of the dome ring is 6" wide and provides a fairly good storage area. Of course as you rotate the dome it gets harder to find things, so I added some conventional shelves curved to fit the wall. The finishing touch was a cool green-blue indoor-outdoor carpet.

This observatory provides us a convenient shelter which makes for more exciting, comfortable viewing nights — and it is something we take great pride in.

Ronald Wisdom
Route 1
Box 369
Beebe, AK 72012

Cutting kerfs in plywood.



Telescopes for the Future

by Kevin Ritschel

Whenever the decade changes, we find reviews of the past decade and forecasts for the future decade throughout the press and popular literature. Astronomy, up to now, has been nearly spared this fate. This article, however, is of just that type: a forecast of how new technologies will make amateur astronomy and telescope building more fun, easier to do, and more rewarding.

I would like to discuss how developments will, or perhaps more realistically I should say "might," affect amateur telescope makers and observers. I will also concentrate primarily on hardware, the telescopes and accessories, rather than the astronomical problems that need to be attacked, or the advances in our understanding of the universe that seem probable.

What prompted me to write such an article? Merely the state of astronomy and technology as it exists in this country today! There are exciting concepts and technologies now being developed that will strongly affect how we go about doing amateur astronomy. And there have been important advances in the field of astronomy, both professional and amateur, such as:

1) Huge telescopes for professional astronomy are being dreamed about. The Kitt Peak National Observatory has recently published the proceedings of a conference, "Optical and Infrared Telescopes for the 1990s": an incredible look at professional telescope technology, some of which will benefit amateurs with "spin-offs" and new ideas.

2) Trends in amateur equipment as shown at the 1980 Riverside Telescope Maker's Conference (snow and all) and Astronomy 80 — the summer meeting of the WAA and the ASP — were toward new types of hardware. New trends are also developing for organized amateur astronomy activities.

3) Advanced electronic technology that can be used by ATMs that is becoming more affordable and more available. New solid-state detectors, TV cameras, image intensifiers, and digital electronics are opening all sorts of new possibilities for very versatile amateur telescopes. These same innovations in instrumentation electronics began to revolutionize the research telescopes (when the technologies were in the experimental stage themselves) starting about 25 years ago.

4) The explosion of products for amateur astronomers in the past 15 years produced by commercial firms. We are experiencing a "positive feedback" situation: new ideas generate good telescopes/products which lead to creative application of the hardware. Those good results create new interest, more ideas, and more hardware for everyone. From the backyard amateur to the larger companies, new hardware stimulates more people to get more results, and those results prompt further developments.

Todays's better coverage of developments has whipped up tremendous excitement in what can be done with readily available hardware. As more people have recognized and responded to this, it has created more demand for products, and a greater diversity at the astronomical hardware smorgasbord has emerged. Well, let's get on with looking at possible developments for the near and not-so-near future of our hobby!

Telescopes for the Amateur

Several trends are quite distinct in amateur telescope building and commercial telescope manufacturing. These will not change in the immediate future (I think):

1) The Newtonian is here to stay! Most amateur-made telescopes still rely on the simple yet excellent optical system of the Newtonian reflector. This optical system provides very good images with fairly wide fields and it can be quite "fast," f/5 or f/6, before aberrations become bothersome. Added to its performance is the fact that Newtonian optics are easy to fabricate in size ranges that many amateurs use, 6-inch to 12-inch. Many amateur telescope makers, and many commercial makers, still concentrate on this simple and proven optical system.

2) Bigger telescopes for amateurs. Twenty years ago the average scope for amateurs was a 3 to 4-inch refractor or a 6-inch reflector. Today it is very common to see the beginning as well as advanced observers with nothing less than an 8-inch. Ten to 14-inchers are very common. Why are we seeing this development? First, new optical configurations (catadioptrics) have made large instruments much more portable. Second, new optical fabrication technology has made larger optics almost embarrassingly inexpensive. A 10-inch f/5.6 paraboloid and flat can be purchased commercially for $125 to $250. It simply isn't worth your time making the optics for a telescope this size, let alone smaller optics, when quality optics are available for such low prices. Third, through the publication of photographs and observations, as well as demonstrations at star parties of large telescopes, many amateurs realize there is no substitute for a large aperture telescope under clear, dark, steady skies for obtaining better views and photographs of their favorite objects.

3) Very large amateur telescopes will be built. We are starting to see some large cheap optics available that make telescopes above 12.5-inches diameter very affordable. The amateurs who have built big scopes are usually the most envied (and their telescopes talked/dreamed about) at conventions and star parties. The urge to see more has driven observers such as the following to build some interesting large scopes: Kevin Medlock's 18-inch; Bill Hornaday's 16-inch (and he has a 24-inch in progress); and Roger Tuthill's 20-inch, to name just a few. These people have exceptional skill and determination. Their examples (and what can be done with their finished instrument) should inspire many of us to gather our forces and attempt large light buckets of our own.

4) The Dobsonian telescope will often

be the first telescope tackled by amateur telescope makers. The Dobsonian is a very simple telescope. Made of plywood and sonotube, it has a simple mount with up/down and left/right adjustments (an alt-azimuth mount) that's easy to make without access to a machine shop. The optics of a Dobsonian are Newtonian, and can easily be made or purchased very reasonably. The Dobsonian is not only a perfect beginner's telescope, it is a simple and effective way of getting those larger aperture optics into use. Lots of big (12 to 24-inch) Dobsonians are in the offing.

5) The pipe mount is dead. Generations of TMs started out by building a pipe-fitting equatorial mounting, perhaps with the belief that they simply had to have an equatorial mounting for the ease of tracking. The literature on making a first telescope is infested with mountings made at a plumbing store. The display of impressively performing Dobsonians, with their simple technology, at conferences and star parties has won over, or soon will win over, the telescope making public. The Dobsonian exhibits good visual performance, and is a far simpler vehicle for starting people off in their acquaintance with the universe than plumbing ever was.

6) Big Schmidt cameras will be built by amateurs who can overcome their fear of making (or the cost of buying) aspheric optics. Big Schmidt cameras are wonderfully suited for wide-field astrophotography; indeed, they have produced some of the most breathtaking amateur and professional photographs ever made.

The Schmidt camera's design yields wide fields, reciprocity-failure-beating fast focal ratios for short exposures, and impressive image quality. A Schmidt also imposes stringent demands as a consequence of its design that must satisfied if good results are to be achieved. A long tube is a drawback in large sizes (say above 12-inch diameter) because the corrector is located at the radius of curvature (or twice the focal length) in classical designs. The fast f/ratio demands that the Schmidt be used under very dark skies or the photographs taken will fog from light pollution/sky glow; the optics are hard to make, and the Schmidt is normally designed for photographic use only. These advantages and disadvantages make the large Schmidt an admirable goal for a dedicated amateur or club.

On the advanced amateur, industrial, commercial, and professional level, the methods for rapid generation, polishing, replicating, and interferometrically testing aspheric surfaces will yield Schmidt correctors that are just as awesome to behold — but much less expensive to produce.

7) There is a movement toward telescopes with "faster" optical systems — optics with f/ratios of 10 or faster. It is common to see Cassegrains and catadioptrics of f/10, f/8, and even f/6, rather than the systems of f/12 to f/23 of the early designs. It is also common to see Newtonians from f/4.5 to f/6, whereas a decade ago most Newtonians were f/8, with an occasional "daring" f/7.

The shift toward faster optical systems seemingly originates from two trends in telescope use. First, there is an increased interest in deep-sky astrophotography and viewing. Many newcomers to astronomy are attracted to the faster optical system because it makes the exposures shorter and therefore less work. It gives wider, brighter views for deep-sky observers. Second, light pollution has forced many amateurs to practice Bedouin-type astronomy: observe here tonight — pack up and move — observe elsewhere tomorrow night to escape the city-illuminated night skies. Bedouin astronomy places a premium on portability. A telescope is much more likely to be carried about and used if the tube is short and light. This is one of the features that a fast optical system delivers.

8) Mirror-lens telescopes will gain popularity because of two primary factors: a) they are very transportable (and thereby easy to use); and b) they have high quality optics packaged for tremendous versatility. You can do just about anything with them given the right accessories.

The future may show a greater variety of commercial catadioptrics. Some with faster f/ratios and/or larger apertures will surely become available for the telescope enthusiast. Although these are rather expensive (because they require much more work to manufacture than, say, a Newtonian), the advantages are generally worth it.

9) The refractor and unobstructed reflector systems are going to remain with us. Despite all that is said, a totally unobstructed optical system yields slightly higher resolution. If an amateur specializes in a field where resolution is his/her dream and breath-of-life, such as planetary or close double star observations, a large refractor or unobstructed reflector is better. While a large refractor is an impressive monument, it is difficult to transport, and many designs suffer from chromatic aberration so that filters are necessary for "colorless" viewing of bright objects. Unobstructed designs (i.e., yolos and schiefspieglers) are costly but neat to use and make.

New Technology, New Accessories

In the next decade or so, we will continue to see individuals and some corporations seek out what they consider the "ultimate" optical system. When you hear talk of "ultimate," however, you must constantly ask yourself, "What does this person want to do with the instrument he/she is building?" If you are looking for the best wide-field photographic instrument, your design will be different from the design favored by a generalist or a deep-sky observer. Different telescopes are different because they're best for different tasks.

If I were to make one generalization, it would be that larger aperture instruments are more versatile and more capable of switching from one area of observing to another than small instruments are. Also, the "ultimate" telescope one person can build is strongly affected by his/her specific skills in optical fabrication and personal preferences in instrument design.

The author of the July 1980 Gleanings article in *Sky & Telescope* is an example of a person seeking the "ultimate." Yet he did not really investigate the Schmidt Camera — even though it is very well suited for the very type of work he considered. Indeed, he even notes the Schmidt camera has "unparalleled performance."

Let's ask a few questions about the radical changes in telescope design and appearance that might be made by new technologies. For example:

1) Can a Schmidt Newtonian optical system be easily built? The parabolic primary eliminates the spherical aberration a conventional Newtonian with an easy-to-make spherical mirror would have. In a Schmidt-Newtonian, the spherical aberration could be taken out by an aspheric corrector plate. Hand polishing could eliminate residual zones by figuring slightly the spherical primary mirror. With the technology available today, corrector plates could be made by commercial companies very easily. The Newtonian-Schmidt type reflector is not new; it is, in fact, outlined in ATM Book 2 in an article on aplanatic reflector design using correcting lens by Wright, and the design is properly called the Wright telescope.

2) Is breakthrough in drives possible? Roller and chain drives could replace the gear drives we see on conventional telescopes. Some examples of these technologies have been in operation for a decade or more — long enough to prove themselves successful. The Stony Ridge Observatory's 30-inch is one such.

3) Will the alt-azimuth mount replace the standard equatorial? Personally, I doubt it very much. An equatorial mount is easy to make for small instruments, especially if you want to track for photography or some other observational program — say,

photometry. On the face of it, using an alt-azimuth for astrophotography would seem to require the sophisticated use of computers. (More about this later.)

4) Might new cameras become available for amateurs? Special instruments with aerial or knife-edge focusing systems would solve many focus problems. We may also see new types of cameras developed and marketed for cold camera photography or photographs with specially treated emulsions.

5) Will better guiding systems be developed? Good off-axis systems for Newtonians are already on the market. A new generation of photoelectric guiders is now possible, relieving some of the tedium in long-exposure work.

6) Will the 80s or 90s see inexpensive accessories for amateurs to study spectra of objects? An easy-to-make accessory for a moderate-sized Schmidt camera or telescope would be an objective prism. Such a prism would look like a "lens" with optically flat surfaces having a two to four degree wedge between the surfaces. The amount of wedge would be different for different telescopes and different applications.

An objective prism would create a field of stellar spectra rather than the conventional spectrum of a single star produced by most spectrographs. This means whole clusters can get their spectrograms taken at once — but a star would need to be bright to visually observe this. An accessory of this type would allow astronomy classes to make spectral surveys with small Schmidts and for small institutions and researchers/amateurs with little equipment to make beautiful and scientifically valuable spectrograms.

7) Will light pollution filters get better? New generation light pollution filters are now being prepared. Perhaps amateurs will utilize them for single emission line observations in conjunction with image intensifiers! Exciting work can be done with visual and photometric use of these filters. Variations of interference filters have been used (and hopefully technology and mass acceptance can drive the cost down) for solar astronomy.

8) Will observers ever escape the cold of cold nights? Well, winter isn't as bad since great improvements have been made in camping gear. Natural down and synthetic materials make very warm outer clothing; arctic boots and down footwarmers keep your toes warm even in snow; electrically heated suits can really take the chill out of an evening; and small catalytic heaters can keep tents and campers warm on a cold winter's night. Now you can look forward to victory rather than frostbite!

9) Will Cassegrain telescopes with rapid-change secondary mirrors be developed for the amateur market? With a change in secondaries, a fairly large instrument could have a fast (f/3 to f/4) Newtonian focus; a medium Cassegrain focus (f/10); or a long Cassegrain or Coude focus (f/15 to f/35). Suddenly, the multipurpose telescope would exist. The trick is to develop sufficiently accurate methods of changing the secondary so that a well-collimated telescope will result. This would make a larger instrument such as an astronomy club's telescope very versatile; it is now a common feature on large professional telescopes. Note that this has been done on some commercial instruments for the amateur (Star-Liner, Cave, and early model Celestrons), but due to the current and foreseeable technology, it will be limited to fairly large instruments (at least 10-inches).

It is certainly possible to make other secondary mirrors for Cassegrain instruments of all sizes. However, the number of people who would know how to (or want to) use them is very limited. This eliminates their introduction in small scopes by commercial companies. We may see more of this type of experiment by amateur telescope makers.

Economics and Marketing

Astronomy is a growing hobby. People are just now becoming more aware of space. The more far-sighted companies that realize that astronomy is a growing hobby and that people are becoming more aware of space and astronomy will do well. They will use new technologies to hold or decrease the cost (relative to inflation) of commercial telescopes. The "market" for telescopes is just beginning to be explored. What kinds of technology will be utilized?

New, faster, and more accurate types of metal working machines such as numerically controlled lathes can greatly reduce labor costs in the metal working phase of a telescope's manufacture. These machines make better parts, more uniformly, and at lower cost than machinists do. Perhaps one day it will be possible for a super-accurate lathe to produce a finished optic from raw stock — from mirror blank to mirror with no intermediate steps! Research toward this goal is being pursued both in this country and overseas.

We will also derive benefits from new material research. Strong, lightweight materials are beginning to be applied to telescope manufacture. It may be that conventional materials such as aluminum for tubes will become too expensive (aluminum, for example, has gone up rapidly in the past few years) and exotic yet strong materials such as carbon-fiber based material may be used.

At this point, please note that commercial firms making telescopes priced within the amateur's budget are not the same companies that are doing basic research in materials science, radical new optical fabrication technologies, solid-state electronic research, and so on. If they were, the cost of the telescopes would be astronomical. Simply not enough of them are made to ever write off the cost of such research. (Basic research is best left to universities and such companies as Perkin-Elmer, TRW, and Rockwell International.)

The new products or accessories you will see on the market or at telescope makers' conferences are the applications of proven technology to develop a new solution to an old problem. The more daring applications of new technology will, I suspect, be made by scientists and engineers who also happen to be TMs and observers as a hobby. (An example of this was the development of photoelectric guiding systems to amateur-size telescopes.)

Now let's point out also a few more rules of economics. There are many interesting and useful accessories and optical configurations that can be made. You may have asked yourself, "Why doesn't company XYZ make it!! I could use it! I might even buy it if it were made!" This is most likely true. A company could make the product, but you might not be willing to pay the price. A new product or custom accessory requires a lot of work and that development and applied research is reflected in the cost of the product. If the product is made once or only a few times, it's going to be expensive — so expensive you probably won't buy it.

Also remember that before a product is made, there have to be people who not only want to buy it, but who *can* buy it. A lot of amateurs want to buy a 200-inch telescope — but I know very few who could. A company, when it develops a product, must look at the product to see if it is affordable and whether anybody wants to buy the product in the first place.

Any company has only so much time and staff to develop new products, and they must make sure that the product is worthwhile and that it will sell. If it doesn't sell in large enough numbers, all those good people who created, designed and produced the product will be out of work when the well-meaning company goes broke!

Electronics for Amateur Astronomy

In no field of technology is the promise for a better tomorrow as bright as the promise of electronic technology to astronomical instrumentation. So much is already possible via electronics — but costs must be reduced before many of

the more exotic applications are feasible. Here are some examples of current and future electronic aids to astronomers:

1) Radio astronomy may develop into a more vigorous hobby than it now is. This could arise from more sensitive and easy-to-use radio telescopes, whether available as kits or finished units. It will take some push by electronic hobbyists to bring their expertise into astronomy, and when they do, TMs and observers must be willing and open-minded enough to enjoy this new way to view the universe.

Radio astronomy, although the results from it are fascinating, will probably never come close in its acceptance or wide-spread participation by amateur astronomers as will optical astronomy, I believe. Why? The impact of the incredible sights possible through an optical telescope will never be duplicated by radio astronomy. Even with a radio telescope that could display radio maps or pictures of the sky, the display is not as "real." It simply will not have the visual impact of a look through an optical telescope — even a small one. Perhaps I'm wrong; if so, I'll welcome the correction!

2) Optical image intensifers are available today at costs ranging from a few thousand dollars up to better ones at least $4,000 to $5,000. As the technology improves, it would be fascinating to couple an improved intensifier onto a telescope which would give very bright, high resolution views at a low cost. A plug-it-in-and-look or turn-key type unit that costs maybe $200 would be a welcome addition to any deep-sky observer's arsenal of accessories.

3) Computers will play an increasing role — not only in astronomy but in every aspect of American home-life. Astronomers will be and are now using computers or programmable calculators to:

a) Analyze errors in the polar alignment of their telescopes.

b) Allow alt-azimuth telescopes to track objects in the sky as an equatorial instrument. In such an application, the computer is only telling the mechanical components of the telescope how they should move in order to follow the sidereal motion of a star, planet, etc.; the computer does not do the moving itself. What's really neat is that the computer can also be programmed to take into account such sources of error as periodic error in the drive system, atmospheric refraction, and telescope flexure, then correct for them to make a uniform drive rate. In order for a computer to function in this job, however, your telescope must have the means of telling the computer where it is pointing. Digital encoders that act as transducers are at present rather expensive (i.e., $10,000 each). The real effort in making a computer-controlled telescope is not programming the computer, but getting the hardware to function at reasonable cost.

c) Keep a calendar and act as a reminding service of important celestial phenomena. The computer will remind you what's up, when to prepare for a star party, when you're low on a special film, and when to prepare for special events such as eclipses.

d) Electronic star charts will allow you to shift your reference not only from one part of the Earth to another, but also to other stars. You may be able to ask an electronic star chart to display only the brightest stars or add successively dimmer sets of stars in, say, 0.1 magnitude steps. By asking an electronic star chart/computer, you can instantaneously call up a more detailed finder chart, or different scales for variables and other deep-sky objects. You'll also be able to call forth torrents of data about any deep-sky object you wish to inquire about.

e) Home/observatory computers will allow the instantaneous reduction of data from a night of photometric photometry, or allow you to calculate orbits of binary stars from your own data of a pair's separation and position angles.

f) More amateur opticians will be doing ray tracking and optical design with home computers. This should help tremendously in the introduction and development of "optimum" optical designs as discussed earlier.

Amateur Groups in Astronomical Education

As amateur astronomy develops and becomes more sophisticated, we will see better efforts to bring the thrill and enjoyment of this hobby to others not as deeply involved in astronomy, and to the general public.

Indeed, the popularization of astronomy by both amateurs and professionals will be only a part of a general effort by all the sciences to bring science to the general public. Why do astronomers and other scientists want to bring understanding of their work to the public? It may be that they wish simply to share the beauty and simplicity they find in nature with everyone; they may wish to share the thrill of discovery they feel when they do science. Or it may be that they are more keenly aware of the social responsibilities and implications science has, and that support for science will come only from a public that understands what science is trying to do.

What type of activities might be developed for increased enjoyment and sharing of astronomy?

1) We'll see much new educational material being developed or introduced. Instruction books on observational astronomy, observatory building and design, and astrophotography will appear.

2) We'll see the new media (such as video tapes) offer instructional material on telescope use and astrophotography. Also new science magazines such as *Science 80* and *Focus* will cover astronomy and bring it to a wider audience.

3) Movies about space and science fiction (*Star Wars*, etc.) will create greater public demand for educational material and events. More classes at community colleges and by astronomy clubs on telescope use and basic astronomy will find students. Clubs will receive more attention when they hold public star parties and Astronomy Day shows. Public lectures on timely topics should be well attended. Public support should, in general, be high especially if efforts are made by conscientious educators and amateurs to foster good relations between the public and astronomers.

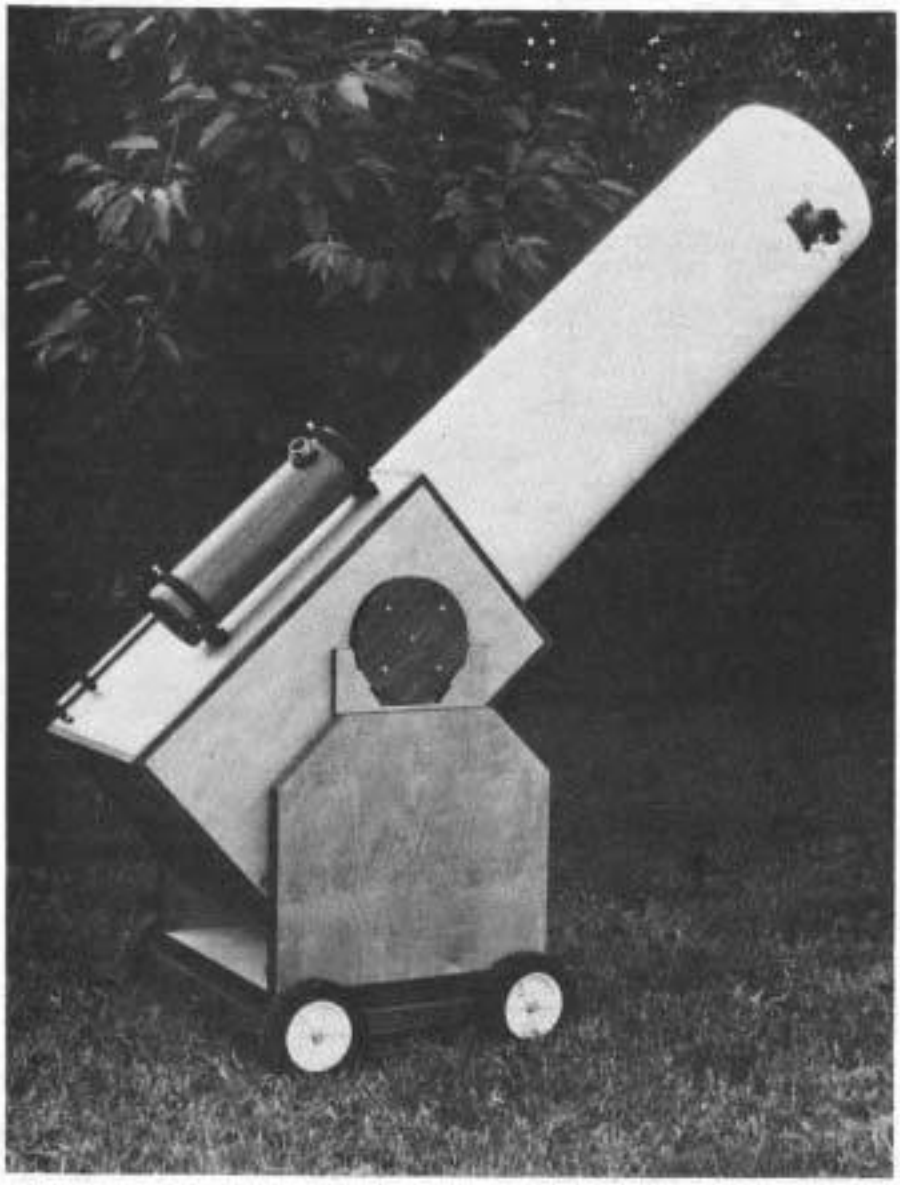
4) Because astronomy is expensive to do, especially the construction of new, large telescopes, more groups will form with the goal of building and operating large telescopes. One can point to the successful groups — Stony Ridge Observatory in California, and Junipero Serra Observatory near the Riverside TM Conference site — as models for such cooperative ventures. Such projects are limited not by technology, but by human nature. Group efforts require a strong group spirit and determination to get the job done. I've seen many more group efforts start, only to fall victim to petty politics, than I've seen succeed.

5) Astronomy is more fun when done with a group, and astronomy clubs are generally social in nature. Amateur groups will go to new heights in their efforts to provide interesting and educational activities for their members.

What I hope I've shown is that technology is going to contribute much to the enjoyment of astronomy in the future. Technology is beautiful! It allows us to see the universe in all its bewildering complexity and someday it may help us see the universe's underlying simplicity and order. Should anyone have thoughts on new developments in astronomy beyond the few I've included here, the author would be delighted to have you write to the address below.

Kevin Ritschel
2014 Verano Place
Irvine, CA 92715

Mr. Ritschel is Celestron International's Manager of Technical and Astronomical Services.



◄3

Birch and Walnut Dobsonian

Sir / Enclosed are several pictures of the 12" f/6 Dobsonian that I recently finished. The mount is made from birch and walnut veneer plywood. The wheels are removable and are used just for transporting the scope short distances on level ground. The finder scope is a 4¼" f/4 which gives a 3½° field at 15 power. It is more useful than any finder I've used before because of its large aperture. The basic design was taken from the articles in TELESCOPE MAKING.

Tom Palmer
2432 Westgate Ave.
San Jose, CA 95125

That's a beautiful job!

Water-white Plate Glass?

Sir / Do you know any source for Water-white plate glass for Schmidt cameras? The St. Gobain Glass Co. used to supply this — can you send me an address? Thank you.

Mark Urbaetis
R.D. 2, Box 250
Redford, N.Y. 12148

Can anyone help Mr. Urbaetis? Does anyone know of a reliable supply of quality plate glass? Please copy TM into your correspondance.

Teflon Source

Sir / Received this date issue #8 of TELESCOPE MAKING. First, I would like to extend my congratulations on a fine publication.

Second, I have noticed since the Dobsonian telescope has arrived on the scene there have been numerous letters concerning the availability of teflon in small quantities. I thought perhaps your readers might be interested in the following information:

The General Electric clothes dryer has used teflon bearings for a number of years. I have enclosed a sample so you can evaluate their worth to the amateur telescope maker, since I have no experience in this field. However, I am the service manager for an appliance repair division and am familiar with a large number of parts.

This package can be obtained at any local General Electric major appliance repair shop as part number WE 3x37, for a cost of approximately $1.00. I would suggest checking the yellow pages for a nearby dealer.

While looking at the article on the Poncet Mounting, the thought occurred to me that the front bearings (which are also teflon glides but premounted on metal brackets) would very easily support the yoke assembly of such a mount. However, if you are interested in further details, you can probably look at the parts of the above mentioned source. The part number is WE 25x60.

Finally, there is an auger motor used in a side-by-side refrigerator which has a threaded shaft and a rotation speed of 16 RPM and is very strong. This may also be useful to some telescope makers. It's part number WR 60x101 and costs about $50.00.

Robert W. Hastings
P.O. Box 367
Manteca, CA 95336

Thanks for your help.

Greater Frequency?

Dear Mr. Berry / Congratulations on a 6th super issue of TELESCOPE MAKING. I feel that this was the best yet. Some of Opticks' customers have asked me to see if there are any plans for the future of going to a more frequent schedule, perhaps every two months. As you will recall, I have been operating my own business for about three years supplying the astronomy enthusiasts in Canada with ATM and other supplies.

B.L. Matthews
Opticks
P.O. Box 129, Station B
Ottawa, ON
CANADA K2C 6C3

— While we currently have no plans for increasing the frequency of TM, we will seriously consider it when the circulation becomes somewhat larger.

Rotated Spikes

Sir / In Robert E. Cox's useful article "Secondary Mirrors and Spiders" in TM #7, there is one rather trivial error. It is implied that the diffraction spikes that grow out of star images lie in the direction of the straight edges that cause them, but in fact they lie at right angles to the straight edges. Thus, four of the five diagrams that make up the second row of the figure at the top of page 6 are incorrect. In the two at the left, the

PEPers gather at the I.A.P.P.C. meeting.

diffraction spikes should have been drawn horizontal, not vertical. In the third, the pattern should be rotated 30°, and in the one on the right, the spikes should be nearer to horizontal than to vertical.

Although getting this right will never be of importance to most astronomers, I feel that for the sake of beginners in double star observing, you should set the record straight.

N.J. Rumsey
Physics and Engineering Laboratory
Dept. of Scientific
and Industrial Research
Private Bag
Lower Hutt, New Zealand

Complete Setup

Sir / My name is Steven and I have wanted a telescope for quite a while, but the price of a 10″ is no cheaper than $1,200. I have a telescope that's rather small — 2½″ to be exact. I can see bright and close things, but when it comes to seeing far away objects, all I get is nothing or just a blur. That's why I want a 10″. As I was looking through ASTRONOMY magazine, I came across the article "How to Build a Dobsonian Telescope." I read through it and wondered if you could put a clock drive, camara adapter, drive correctors, manual declination and R.A. control, and other items to assist you in photographing the stars.

Steven Veit
3 Welsh Court
Wayne, New Jersey 07470

Steven: The basic 10″ telescope described in ASTRONOMY was designed so that it could be placed on an equatorial mounting if the owner so desired. That's not what the Dobsonian design is all about, however. Dobsonians are the elegant and inexpensive way to go for visual observers. We'd suggest you start saving that $1,200 right now.

Advertising Opinions

Dear Mr. Berry/ In reply to your editorial of TM #7, I feel you must be very cautious in introducing display advertising.

I feel strongly that there should be a maximum ad size, to prevent the "big boys," with almost unlimited advertising budgets, from taking over. Perhaps a standard size of one column by 3″ tall (9 ads per page), plus a smaller size of one column by 2″ tall (12 ads per page) would serve.

I also feel that you should discourage, or even ban, ads for complete manufactured telescopes, with complete defined as a "ready to go optical package on a mounting." Most manufacturers sell componant parts and accessories as part of their lines. Let them tell us about those! TM should remain devoted to those people who build, rather than buy, their telescopes.

I also think TM should have a low cost (but not free) classified section, with no more than a two month lead time. This would serve those serious TMs who need to locate, or have to sell all those hard-to-find items.

John Allseits
800 E. Allanson Rd.
Mundelein, IL 60060

Sir/ I think that TM should have advertising. However, no advertisements for completed telescopes should be allowed. After all, the name of the magazine is TELESCOPE MAKING, not Telescope Buying! This would help the readers to find out who sells what types of materials and accessories that are hard to find or difficult to make.

Please convey my thanks to Mr. Robert Cox for his article on telescope spiders. His suggestion for a spider with wire vanes was perfect for a project in my Engineering Graphics class at Georgia Tech. I plan to use this idea on my next telescope. I'll let you know how it turns out.

David Roberto
2858 Spruce Point Rd.
College Park, Georgia 30349

Sir/ Here are the reasons I don't think you should include advertising in TM: 1) At present, I receive three other astronomy magazines (of which ASTRONOMY is one). 2) There are plenty of advertisements in the other magazines to keep readers informed. 3) As to promoting healthy competition, I feel there are already enough astronomy magazines on the market now that do that. 4) I find your Blue Pages helpful and more then adequate. Plus, I like TM and it's the only magazine that doesn't have [display] advertising in it.

The only reason I can see for including advertising in TM would be if inflation increased the cost of producing TM that it would cause a big increase in subscription price.

Stephen L. Havens
16 Pine Tree Rd.
Keeseville, N.Y. 12944

Our printing bill goes up with every issue.

Programming Query

Sir/ Didn't get to meet you at Riverside, but I have heard much about you and ASTRONOMY from Ron Royer. We've been friends since 1972, when we attended the optics courses at Citrus College in California together. I hope to begin contributing articles to TM soon, since I've got several projects going, or finished, that would be fun to write about.

Regarding your editorial, I think it's a GOOD idea to have advertising. However, too much dealer display advertising of Celestrons — over and over and over and over and over again (like *S&T* and ASTRONOMY) gets really dull. We all know what they look like.

On the other hand, simple listings of products with pictures (especially when the products aren't well known) is beneficial to both the magazine and the readership.

Now that I've answered your question, would you answer one of mine? What is your feeling about publishing computer program listings in TM? I have a number of optical computation programs that I

48

The Amateur Space Telescope Project

by Jesse Eichenlaub and David Marat

Even before the dawn of the space age, astronomers dreamed of having telescopes in space, far above the distorting and obscuring atmosphere of Earth. With much help from various governments, these dreams became reality for professional astronomers during the 60s and 70s. Over the years, bigger and bigger telescopes were launched, until finally NASA started development of the Large Space Telescope — an instrument that will be able to outperform any telescope on Earth.

Meanwhile, the amateur astronomers have had to content themselves with reading about NASA's exploits while standing in the rain under mercury vapor streetlights, with the thick clouds above glowing brightly from the reflected light of cities below. Advanced space hardware was beyond the financial and technical reach of everyone except organizations like NASA and the Soviet Space Agency.

However, over the past several years, developments have been occurring in the fields of electronics and space transportation that will soon change all of that. Realizing this fact, in early 1979 a small of people at Rensselaer Polytechnic Institute, at Troy, NY, started to seriously consider the possibility of building a small amateur astronomical satellite for launch on a Space Shuttle. Over the past year, this has grown into a major effort to design, build, and launch an 18"-aperture free-orbiting astronomical telescope that could be made available to amateurs, professionals, and educational institutions before 1985.

A Short History of Amateur Satellites

In order to put all of this into perspective, it is necessary to go back, for a moment, to 1961. It will probably come as a surprise to most people that amateur-built satellites are really nothing new. Amateur radio operators have been constructing them since the early 60s. The world's first non-governmental satellite was put together in the garages and basements of southern Californians by a group of "hams" calling themselves the Project OSCAR (Orbiting Satellite Carrying Amateur Radio) Association. The 10-pound satellite was given a free launch as ballast aboard a rocket carrying a much larger professional satellite in December of 1961. It broadcast "HI, HI..." in Morse code until its battery went dead three weeks later. Hundreds of hams from 28 countries picked up the signals from its tiny, 100 mW beacon. Variations in the speed of the Morse code transmissions provided information about the satellite's temperature.

Over the next two decades, the hams launched seven more satellites of increasing complexity. All but two have been two-way communications satellites allowing the radio operators to greatly extend their range in certain radio bands. All of these satellites have received free "piggyback" launches on U.S. rockets. Money for their design and construction, typically around $50,000 per satellite, has come almost exclusively from the amateur radio community.

Since 1969, the construction and launching of the ham satellites have been coordinated by a non-profit corporation called Radio Amateur Satellite Corporation to carry on the work of the Project OSCAR Association. Usually called AMSAT, they are headquartered in Washington, DC. AMSAT's first project was to find a free launch for, prepare, and test an amateur radio satellite built by students at the University of Melbourne, under the direction of the Wireless Institute of Australia.

OSCAR 5 was launched on January 23, 1970, and was the first amateur satellite to be used for educational purposes. OSCAR 6 was used for experiments in disaster relief, medical data tranmission, and intersatellite linking. AMSAT-OSCARs 7 and 8 were similar in function to #6, and were launched in 1974 and 1978, respectively.

By the mid 70s, AMSAT had started what it calls Phase III satellites. These satellites will use solid fuel kick motors to boost them into highly elliptical orbits, with apogees (highest points) of around 24,000 miles. When in the highest portions of their orbits, they will be able to cover almost an entire hemisphere of the Earth. The first of these, AMSAT-OSCAR 9, will be launched aboard one of the European Space Agency's Ariane boosters in 1980.

The AST Project

Amateur astronomers got into the satellite building business in January 1979, when the previously mentioned students at Rensselaer realized that recent — and ongoing — technological developments (such as solid-state TV cameras and microprocessor hardware, two of the most useful examples of newly available commercial equipment) would soon make it possible for technically competent amateurs to build an astronomical satellite. This was based on several facts:

1) All of the electronic hardware necessary to build an orbiting astronomical telescope is available "off-the-shelf" to anyone who wants it.

2) Even very advanced electronic equipment is relatively inexpensive, and a lot of it is going down in price.

3) There are a lot of people around, professional, student, and amateur, who are thoroughly familiar with this equipment.

4) Technical literature on the design and construction of satellites is freely available, as is the expertise of professionals who have experience in the

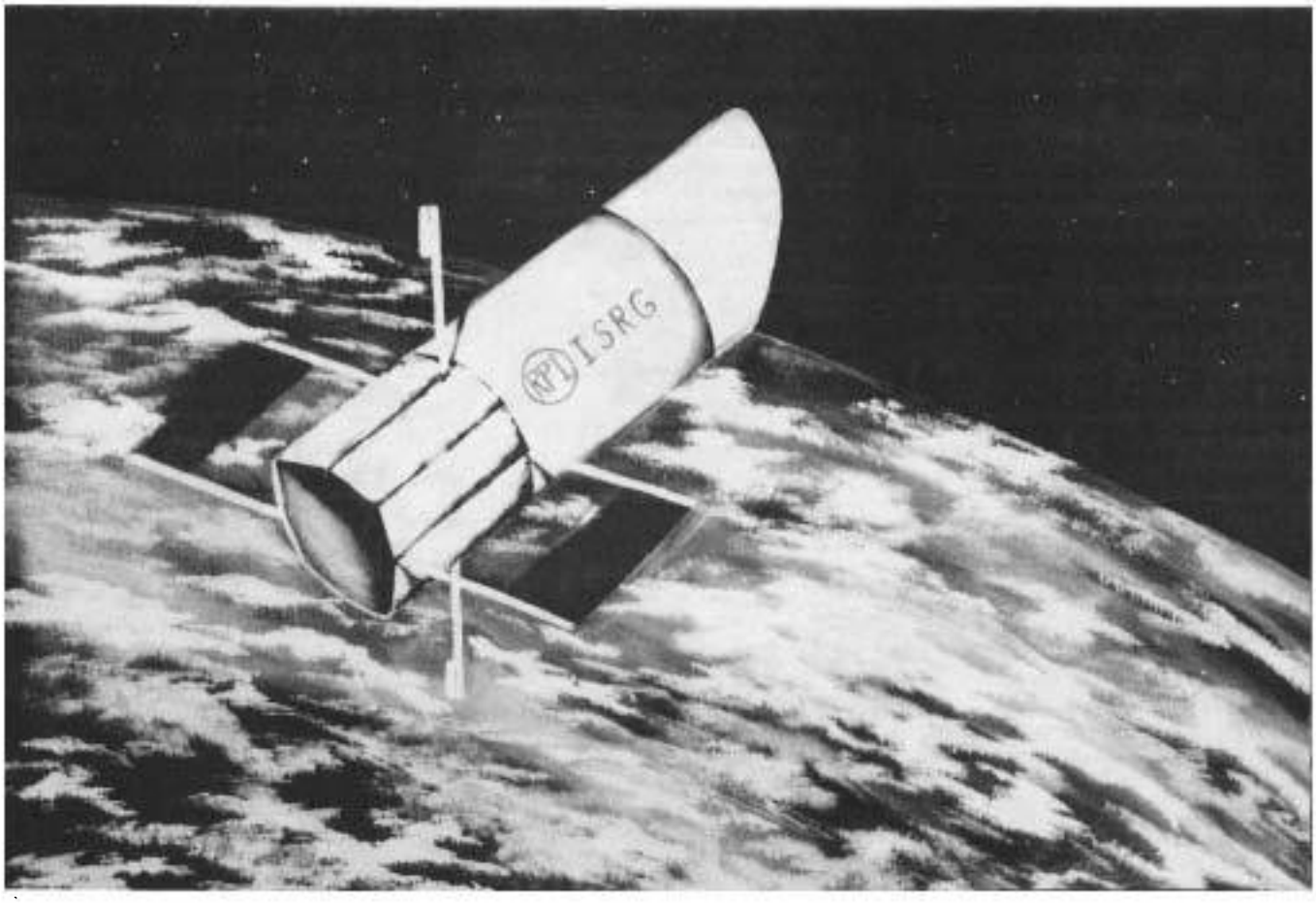
field.

5) Several inexpensive launch options will soon become available. These include the Space Shuttle and several foreign conventional rockets.

6) With enough people well-versed in various fields, free labor could be used exclusively on the project, thus limiting costs to documents, materials, launch, and red tape.

7) In our own case, the resources and expertise found at RPI could be used extensively. Resources include access to all the computing facilities that anyone could possibly want, piles of electronic testing equipment, large vacuum test chambers, several fully-equipped machine shops, and a ham radio station with all the equipment needed to control a small satellite. Expertise would come from faculty members, who include experts in almost every technical field, plus those who have worked professionally in the aerospace field. Furthermore, much of the design and construction work can be done by students for course credit or master's projects. In a few cases, this is already being done.

The Amateur Space Telescope (AST) project was originally envisioned as a private affair that would result in an orbiting 6" Cassegrain telescope with an electronics and attitude control system that would fit inside the smallest of the Space Shuttle "Getaway Special" (GAS) containers during launch. It would occupy a 1.5 cu. ft. cylindrical container, 19.75" in diameter and 10.6" long. At



Painting by Loretta Latendre and Craig Mackenzie

some time after the Shuttle achieved orbit, the satellite would be ejected. We hoped that the total cost of the project could be kept below $15,000, and spread out over five years. Most of the money would come from personal sources. Data would be picked up by equipment similar to that used by amateur meteorologists to get pictures directly from weather satellites. We'd use parts from RPI's ham radio club.

During the spring and summer, we did a general feasibility study to determine whether or not the construction of a space telescope was really a viable project. We obtained information on NASA's Shuttle launch options, examined the resources of RPI in detail, and estimated size, weight, and cost for major components. We were encouraged by the fact that other people had done things similar to what we were planning to do — and with a 100% success rate, too. We began to look into the less expensive piggyback launches, and began to see definite advantages to broadcasting data and pictures over amateur radio bands, to be picked up by OSCAR stations.

Over this time period, the nature of the AST project slowly changed. Apparently, not much useful could be done with a 6" telescope, even in space, but something larger might be of scientific value. It became doubtful that we could squeeze all of the necessary equipment into the smallest Getaway Special volume anyway.

Furthermore, it became apparent that a really long lifetime satellite would cost a lot more than $15,000 to build and launch. At the same time, we were encouraged by AMSAT's good fortune in funding the OSCARs, which cost them from $50,000 to $250,000 apiece. As a result, we began to think in terms of building a larger telescope onboard a satellite that would fit inside the largest of the Getaway Special containers (a 5 cu. ft. cylinder, 19.75" in diameter and 28.2" long). We finally came up with the present design, an 18" collapsible Cassegrain design, as a goal.

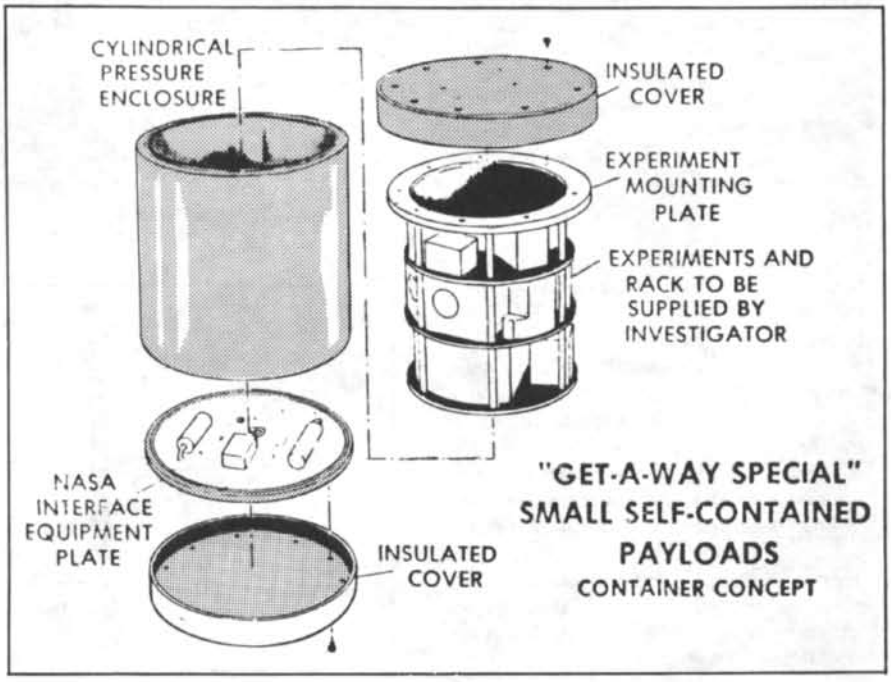
Although the satellite is being designed for the GAS launch option, it is not at all certain that this is what we'll use. Among other things, NASA has yet to set any definite policy on the ejection of GAS packages into free orbit. However, whatever fits into a GAS container will fit anywhere else, so by keeping within the size and weight constraints of that classification, we are maximizing our possible launch options. It now appears more likely that AST will be launched under a new Modest Payloads classification onboard the Shuttle, or as a piggyback payload on one of the ESA's Ariane boosters.

With the possibility of a much larger telescope, and much more room to put equipment, the nature of our project has changed. An 18" telescope with a full compliment of astronomical detectors would actually be scientifically and educationally useful. So our goals have changed from the construction of a small orbiting telescope for the use of students at RPI to the construction and operation of what will, in effect, be a public observatory in space — to be made available to any amateurs, professionals, or educational institutions with worthwhile projects in mind.

AST Working Design

The Amateur Space Telescope is currently designed as a cylinder 19.75" in diameter and 70" long. An octagonal prism-shaped section in the back holds the electronics and attitude control hardware. The telescope is located in the cylindrical midsection. A light shield at the front serves to keep sunlight out of the telescope tube, so that scattered light from the tube walls won't fog pictures. The rectangular panels protruding from the sides of the octagonal section are solar panels to provide power. The solar panels will fold into the octagonal equipment bay during launch.

If a Getaway Special is used, the telescope tube section would be designed to slide over the octagonal section during launch. This would bring



the Cassegrain baffle back to rest on the light baffle tube in the center of the primary. Designing an extension and clamping mechanism to bring the secondary into a precisely aligned position after the tube slides out will be difficult — but not impossible — and there are ways to do it.

Optics

The telescope will employ a Ritchey-Chretien Cassegrain optical system with an 18" primary mirror of about 36" focal length (f/2). The focal length of the telescope will be 360" (f/20). This design was chosen because of its ability to provide sharp, coma-free images over a relatively wide field. With these fields, astigmatism poses no problem. The image should have diffraction limited resolution across the "high power" field of view.

Optical Instrumentation

The detectors will be located directly behind the primary mirror in the first several inches of the octagonal section. Included will be a solid-state CID TV camera, three photometers, and a UV spectrograph.

A second TV camera looking out along one side of the satellite will function somewhat like a finderscope. However it will be used only for the initial attitude determination, or in the event that something goes wrong. The telescope will otherwise rely on internal attitude controls.

In our current working arrangement, light coming through the hole in the main mirror will be deflected to the detectors by a dichroic (selective filter) mirror that reflects some wavelengths of light (the visible regions of the spectrum), but lets other spectral regions pass through. Visible light will go at a 45° angle to a TV camera, and the UV and IR will go on to the photometers and spectrograph slit.

The photometers and spectrograph will look at parts of the same field that the TV camera sees — but in a different band of wavelengths. This will allow us to position objects in the spectrograph slit and the photometer apertures by positioning them correctly in the TV field. The onboard microprocessor may handle guiding.

The TV camera will handle photography and photometry in the visible and near visible region. Solid-state TV cameras are easier to use for astronomical purposes than the common vidicon or orthicon types, and they also consume less power. By simply exposing the imaging surface of the TV camera to light continuously (instead of reading it every 1/30 of a second), an image, in the form of a charge, will build up. A time exposure of several seconds may be built up before various kinds of noise begin to degrade the picture. To eliminate noise problems, we will read-out the image several times per second and repeatedly add it to the accumulative "image" in the microprocessor memory while performing a digital noise cancellation procedure. We will further reduce noise problems by cooling the camera, which is easy to do in space by simply letting heat radiate away. We should be able to obtain the equivalent of several-hour-long exposures in this way. Our goal is a 10-hour exposure capability.

The TV camera could also be used for photometry in the visible and near-infrared region. Present day commercially made TV cameras of the type that we need are sensitive to the near infrared, the visible, and a little bit of the UV.

A lens wheel and a filter wheel will be situated in front of the camera. The filter wheel will hold several filters for photography and photometry. The lens wheel will contain at least two lenses: a simple relay lens for "wide-field" work (around 12'), and an "eyepiece projection" lens for diffraction-limited imaging of a very narrow (around 2') field of view. The exact fields will depend on the final choice of camera.

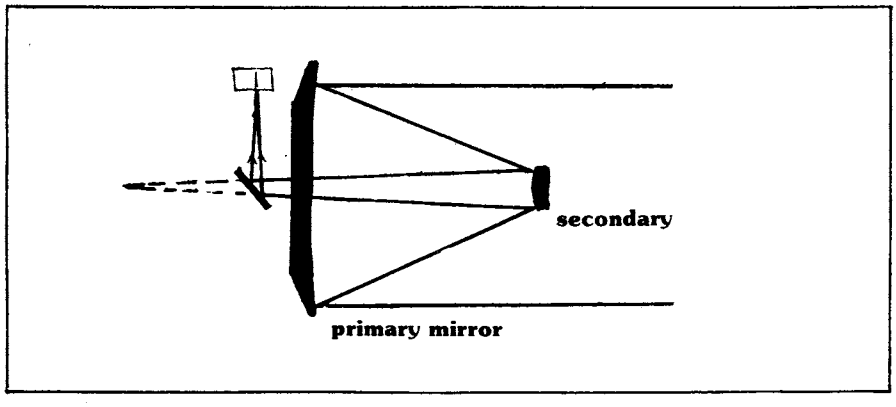
The Photometers will be used for photometry in the near UV, the far UV, and probably a bit farther into the infrared. These will be solid-state devices rather than the commonly used photomultipliers.

The spectrograph, now being designed, will be folded up in the big empty space around the other instruments. We are attempting to come up with a design that will give the highest resolution possible given the allotted space and present-day detector arrays. The spectrograph will probably be used only for UV work.

Attitude Control

The attitude control system of a satellite controls the satellite's orientation in space. On astronomical satellites, the system has two functions — to turn the satellite so that the telescope is pointed at a desired object (called "slewing"), and to keep the telescope pointed at the object for long periods of time (called "fine guidance").

In the case of the AST, the slewing



system should be able to swing the telescope around to within 1′ of arc of any object so that any object can be acquired directly in the "high-power" field of view. The fine guidance mechanism will have to keep the telescope pointed to within 0.1″ of arc so that nearly-diffraction-limited pictures can be taken.

There are several forces in the space environment that tend to turn the satellite away from its targets. The culprits are tidal forces, solar radiation pressure, magnetic effects, and atmospheric drag. Although incredibly small at the 500-mile height at which the AST will be operating, they are capable of turning the telescope away from its targets, and if left unchecked, starting it tumbling randomly.

The required pointing and tracking accuracies have been regularly attained by the designers of space telescopes. Very precise control mechanisms are required, and these will undoubtedly pose one of the greatest challenges in the project.

Two types of attitude control mechanisms meet the accuracy requirements imposed by a space telescope — gyroscope systems and flywheel systems. We are beginning to favor flywheel systems. These take advantage of the conservation of angular momentum; when a flywheel is accelerated inside a satellite, the satellite starts turning in the opposite direction.

Three flywheels with their axes aligned in perpendicular directions are often used in satellites. A fourth wheel with its axis diagonal to the other three would act as a backup capable of replacing any of the other three. By correctly choosing the flywheel masses and sizes, it is possible to use the same set for both slewing and fine guidance.

Flywheels don't run out of fuel. They can operate for years, on solar power, until their motors or bearings wear out.

The satellite design itself will also aid in fine guidance. The weights and solar panels sticking out the side, for example, will balance it in such a way that tidal forces will have almost no effect. Circuitry can be placed so that electrical currents will not produce any overall magnetic field that would rotate the satellite in the Earth's magnetic field.

The Microprocessor and Housekeeping Unit

An onboard microprocessor, a command decoder, a data encoder, and over 64 K-bytes of memory will be included on board. The microprocessor will keep track of all the satellite's functions and lifesigns, regulate temperature and power, help translate commands into action, encode data for transmission, aid in attitude control, and integrate time exposures.

Generally speaking, the microprocessor will be designed to handle only what cannot be easily handled from the ground. It is less expensive to build a component for use on Earth than it is to build one for use in space. Besides, you can repair things on Earth.

Incidentally, there is no hope of using a Space Shuttle to retrieve the AST should something go wrong. It would be much cheaper to build and launch a new satellite.

The Power System

Power requirements for the AST will be low, seldom exceeding 10 watts. Most of the time it will just be sitting there exposing pictures, occasionally turning a fine guidance flywheel or two. Power to the various components will be supplied by batteries. These, in turn, will be kept charged by the solar panels.

Data Transmission and Reception

We would like to transmit telemetry and data over amateur radio bands to maximize the accessibility of our satellite. The satellite's transmitter should be compatible with existing amateur Earth stations which are now used to get pictures from weather satellites or communicate with OSCARs. For a satellite in a 500-mile circular orbit, a few watts output is all that's really needed. The relatively simple equipment needed to pick up the signal would cost only a few hundred dollars to build. A typical installation would be used to record signals on tape for later conversion to strip chart records or pictures.

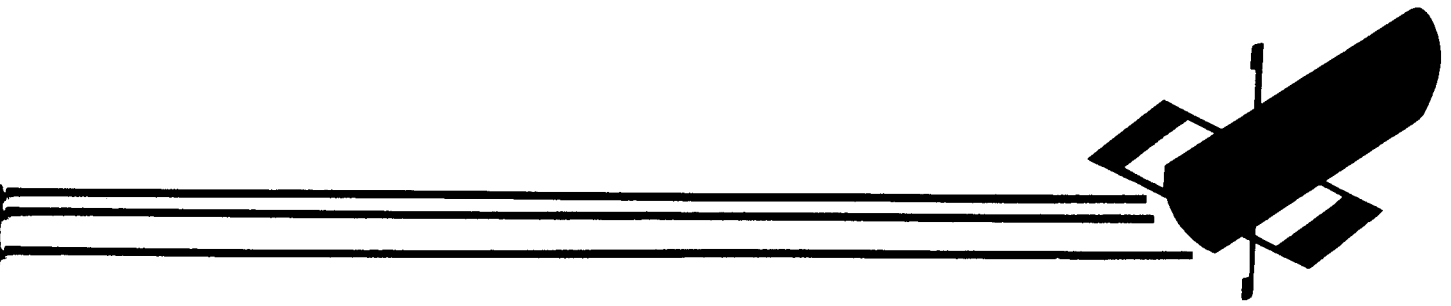
AST Ground Stations

When operating a satellite, it is desirable, and sometimes necessary, to have a worldwide ground station network on hand to control the device and receive data from it. NASA has such a network, but since ours is not a NASA satellite, we wouldn't be able to make use of theirs. The problem of acquiring the use of several satellite Earth stations scattered around the world has thus been of major importance to the project since its inception.

Fortunately, there exist throughout the world thousands of privately owned Earth stations that are used to pick up signals from satellites. Most of these stations are ham radio OSCAR setups, and many of the rest are used to get pictures from weather satellites. Some of these stations are undoubtedly owned by people with an interest in astronomy, and they might be interested in participating in a control network particularly if we offer them some personal time on the telescope in exchange for their help.

Of the two types of amateur Earth stations, the OSCAR setups seem best suited to our purposes, so the AST will be designed with their use in mind. First, they are equipped for both reception and transmission. Second, there are already a lot of them around. Third, a network of OSCAR stations is already organized to keep track of the OSCARs. Many of these stations are extremely advanced, automated affairs, and might be able to handle another satellite. Also, most universities have ham radio clubs, most of which own advanced installations. These would allow university-based users to get their data directly at a convenient, local station.

For the most part, control of the AST would be in the hands of the member stations of the network, acting on



instructions from the controlling organization. On some occasions, limited control of the satellite might be given to some outside group, but only under close supervision. For example, advanced observational astronomy classes could be allowed to get some "hands-on" experience in operating an instrument in space.

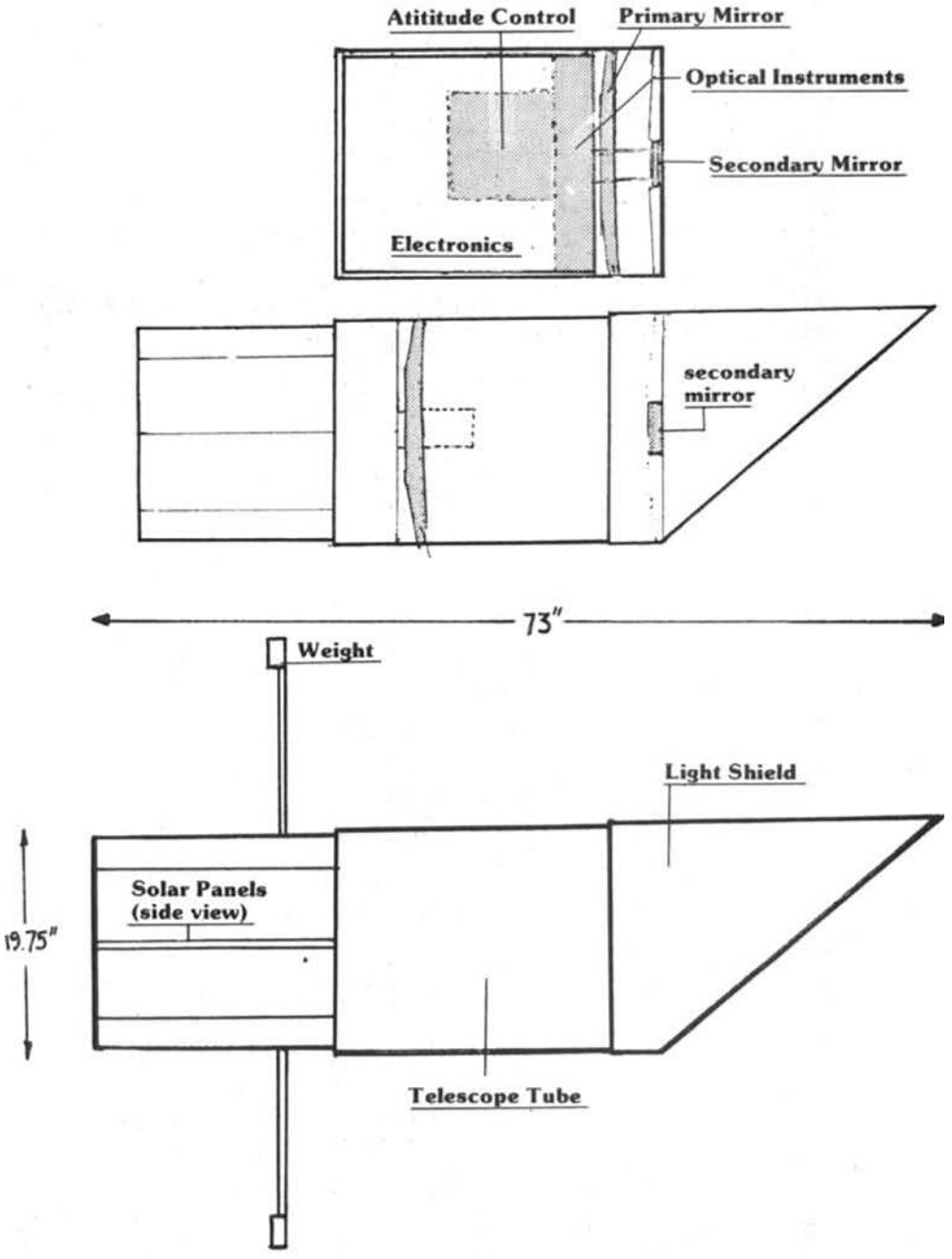
Capabilities

There are three main advantages to doing astronomy from space, all of them resulting from being outside Earth's atmosphere. First, you can "see" in any wavelength, your choices being limited only by the equipment. Second, it is possible to take diffraction-limited, rather than "seeing-limited," photographs. And third, it is possible to take very long time exposures without worrying about scattered light from the atmosphere fogging the image (not to mention clouds, etc.).

The AST will be designed to exploit these advantages to the fullest. With a very smooth and accurate fine guidance system, it should be possible to take pictures with resolutions of about 0.3″ of arc, at least in visible light. Even the largest telescopes on Earth can't do much better than that, and most of the time they do worse. For them, resolution is limited by turbulence in the atmosphere, which tends to blur even short exposure photographs. With the aid of computer picture enhancement techniques, the AST should be able to consistently get pictures that are comparable to some of the finest now taken from Earth.

With a high quality TV camera operated in the correct manner, it should be possible to expose pictures for 10 hours or more. Such an exposure could get down to around 21st magnitude. The sky fog limit for an identical telescope on the ground is only about 19 — even with no light pollution.

An image intensifier might be included to cut exposure times by a factor of 100. Image intensifiers produce noise of their own, though, which is typically about as



bright as background skyglow on Earth. Unfortunately, a single cosmic ray striking such a device would completely ruin a picture. It might be possible to virtually eliminate these problems with proper shielding and noise reduction techniques similar to those used with the camera itself. If so, an intensifier would allow the camera to detect stars with magnitudes in the mid-20s.

Uses of the AST

The AST will certainly be the most accessible scientific satellite in existence. It will be made available to anyone who has a worthwhile project in mind, whether it be scientific in nature, or for educational/demonstration purposes. In addition, the use of amateur radio bands and an almost isotropic antenna on the satellite will allow pople over a wide area, with simple equipment, to pick up pictures and other data directly from the satellite whenever it's above the horizon and transmitting. We may even broadcast particularly interesting data repeatedly — just for the benefit of people "listening in."

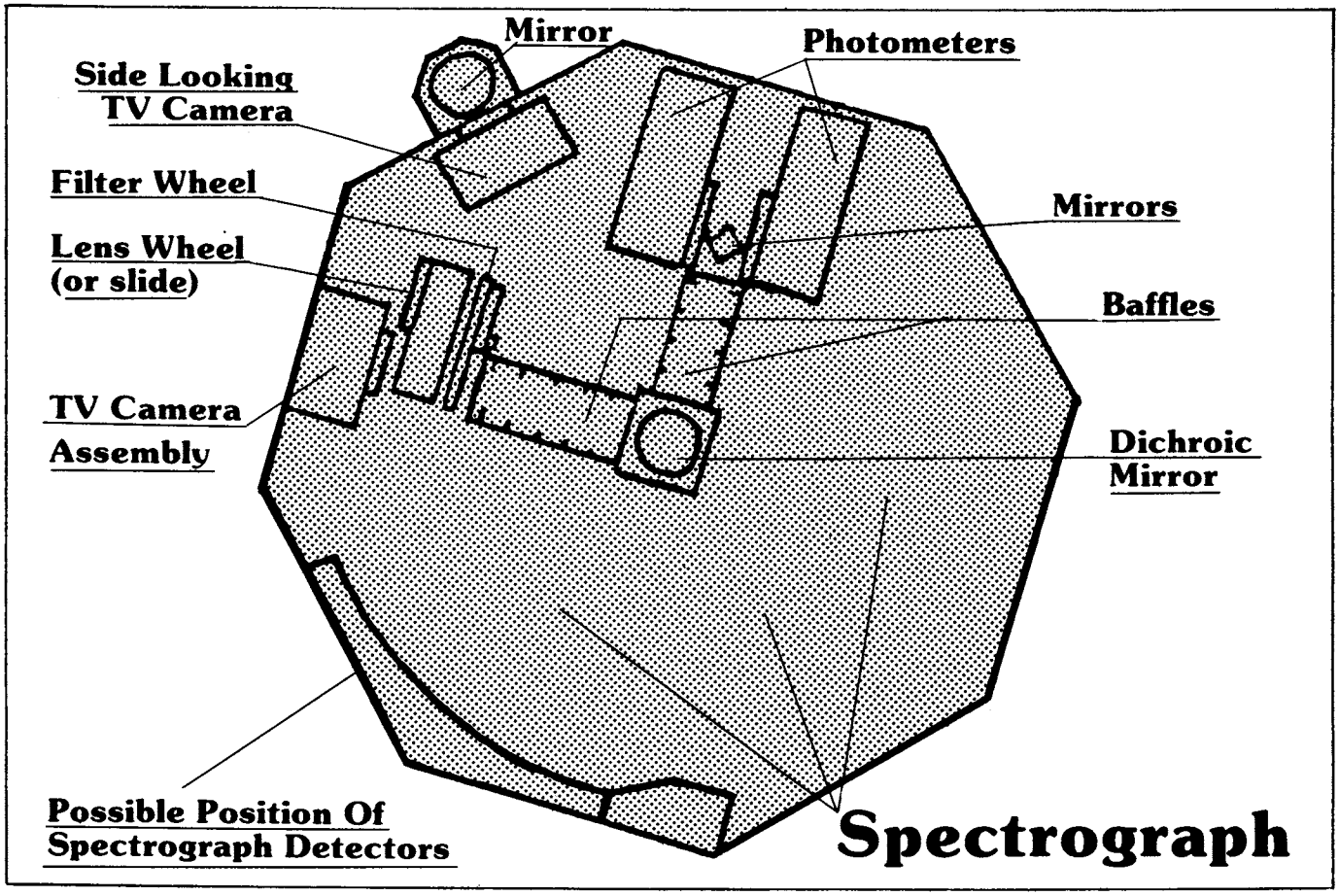
The major uses envisioned for the AST can be divided into three categories: user projects, educational projects, and survey work.

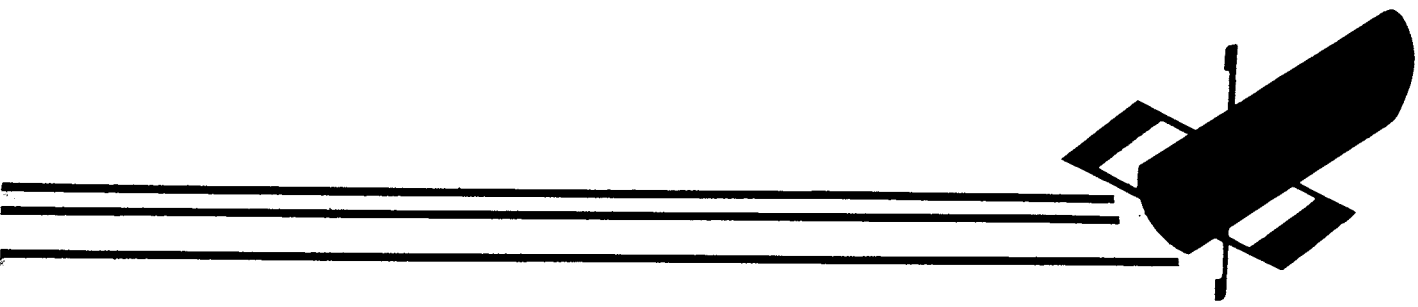
User Projects

User projects will include any scientifically useful investigations carried out by amateur astronomers, professional astronomers, or others. Potential users would contact the controlling organization, which would schedule the required observations in an available time slot. Sometimes observations would be carried out merely on instructions from the user, and the results (i.e., data tapes) sent to him or her in the mail. At other times, the user may want to be present at a control station during the observations (or linked to one by radio) to allow a flexible schedule and direct interaction with the satellite.

Educational Projects

Educational projects will include





activities carried out primarily for educational or public demonstration purposes. Such observations might also be scientifically useful, and thus overlap with the first category. Potential users in this class are faculty members at almost any educational institution of any level anywhere in the world, amateur astronomers with shopping mall displays, and our own organization.

Survey Work

Survey work will include observations carried out by the controlling organization for the benefit of astronomical catalogs and data banks. Some suggested examples include the extension of stellar spectra catalogs into new bands, keeping track of certain variables in the infrared, and taking photographs of planets on a regular basis (although the Large Space Telescope will probably be taking care of that). These are the kinds of activities small observatories on Earth take care of, while the big telescopes tackle the tough jobs. It shouldn't be any different in space.

The Project: As It Stands Now

The AST project is now well into the "R&D" phase. We've spent the past year digging up information on how professional do things, what components are available, and what alternatives are possible. Members of the ISRG, now numbering 15 at RPI and five elsewhere, have divided into various "project groups," each concerned with a different area of satellite design or construction (such as optics, attitude control, or data transmission). Some people are doing this work for course credit under the supervision of professors.

All major design work on the AST is scheduled to be completed in mid-1981, after which funds will be sought to begin actual construction, remaining ground-based experimentation with components, eventual testing, and launch. Launch will occur in late 1984 or shortly thereafter. All launch options are booked up until then.

We have also started work on a simple "test satellite" to send up as a piggyback payload in 1982. This device, to be constructed under the auspices of RPI (for the most part), is mainly intended to give our organization and the proposed worldwide network some "hands-on" experience in building and operating a satellite before the more complex AST is sent up. It will employ simpler versions of many components of the AST, and is in effect being designed along with the AST. Aboard will be the three-axis attitude control system, a star tracker, a TV camera looking out the back, communications equipment, power supplies, etc. No fancy optics will be included; instead the extra space will house a few other experiments from RPI.

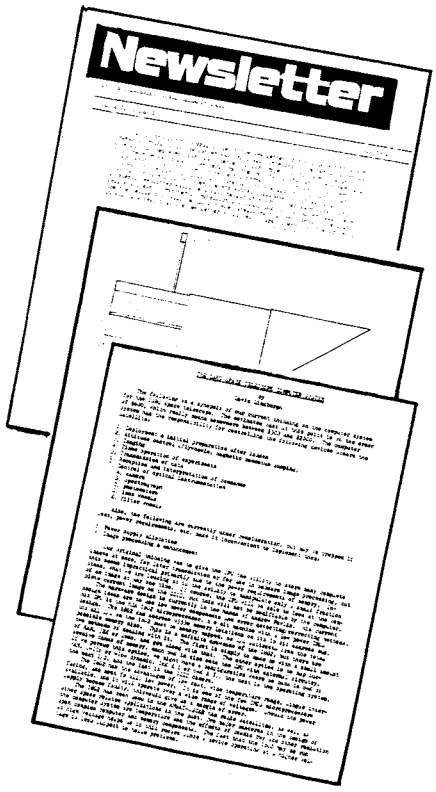
We have also been contacting professional persons and organizations who are directly involved in space astronomy and satellite construction, for the creation of an official advisory board capable of reviewing all our designs and plans along the way.

A project like ours involving the talents and labor of dozens of people in several areas of the country, over a period of five years, requires a high degree of coordination and management. For that reason, we have set up a non-profit organization (the Independent Space Research Group, or ISRG) that has the primary responsibility for the management of and fundraising for the AST project. The organization also hopes to eventually branch out into other areas of scientific and educational space activity as time, money, and manpower permit. However, we don't plan to abandon amateur astronomy after the AST goes up. The prices of both hardware and launches should be coming down drastically over the next few decades. This means that as time goes on, an organization like ours could build larger and more advanced astronomical satellites. It could even become the AMSAT of the astronomical community.

ISRG now publishes a newsletter, too. This was originally intended as a method of keeping everyone in the organization up to date on what everyone else was doing (particularly the out-of-town people). However, many amateurs asked to be kept informed on the project, so we have decided to gear the newsletter to all interested parties. It deals with the AST, the ISRG, space astronomy, "high-tech" amateur astronomy, space transportation systems, and whatever else is relevant. The ISRG has also opened up a supporting membership class.

Anyone who wishes more information on any of this may send an SASE to:

The ISRG
c/o John Grinder
137 Hoosick St.
Troy, NY 12180.



Blue Pages

Classified Pr

see Editorial on page 2 for important coming changes

BOOKS/INFORMATION

Celestron International .....
2835 Columbia St., Torrance, CA 90503
(213) 328-9660

Edmund Scientific Company .....
101 E. Gloucester Pike, Barrington, NJ 08007

OPTICA b/c .....
4100 MacArthur Blvd., Oakland, CA 94619
(415) 530-1234

DRIVE ELECTRONICS

Edmund Scientific Company .....
101 E. Gloucester Pike, Barrington, NJ 08007

Meade Instruments Corporation .....
1675 Toronto Way, Costa Mesa, CA 92626
(714) 556-2291

DRIVE GEARS

Edmund Scientific Company .....
101 E. Gloucester Pike, Barrington, NJ 08007

DRIVE MOTORS

Edmund Scientific Company .....
101 E. Gloucester Pike, Barrington, NJ 08007

EYEPIECES

Celestron International .....
2835 Columbia St., Torrance, CA 90503
(213) 328-9560

Coulter Optical Co. .....
54121 Pinecrest Rd., Idyllwild, CA 92349
(714) 659-2991

Dodd Co. .....
7795 W. Ridgewood Dr., Parma, OH 44129
(216) 886-2828

Edmund Scientific Company .....
101 E. Gloucester Pike, Barrington, NJ 08007

Meade Instruments Corporation .....
1675 Toronto Way, Costa Mesa, CA 92626
(714) 556-2291

OPTICA b/c .....
4100 MacArthur Blvd., Oakland, CA 94619
(415) 530-1234

W.R. Parks .....
P.O. Box 6683, Torrance, CA 90504
(213) 532-6066

FILTERS

Celestron International .....
2835 Columbia St., Torrance, CA 90503
(213) 328-9560

Edmund Scientific Company .....
101 E. Gloucester Pike, Barrington, NJ 08007

Meade Instruments Corporation .....
1675 Toronto Way, Costa Mesa, CA 92626
(714) 556-2291

OPTICA b/c .....
4100 MacArthur Blvd., Oakland, CA 94619
(415) 530-1234

W.R. Parks Co. .....
P.O. Box 6683, Torrance, CA 90504
(213) 532-6066

LENS BLANKS

Edmund Scientific Company .....
101 E. Gloucester Pike, Barrington, NJ 08007

LENSES — CUSTOM MADE

Edmund Scientific Company .....
101 E. Gloucester Pike, Barrington, NJ 08007

LENSES — OFF-THE-SHELF

Edmund Scientific Company .....
101 E. Gloucester Pike, Barrington, NJ 08007

OPTICA b/c .....
4100 MacArthur Blvd., Oakland, CA 94619
(415) 530-1234

MIRROR BLANKS

Edmund Scientific Company .....
101 E. Gloucester Pike, Barrington, NJ 08007

oduct Directory

MIRROR KITS

Edmund Scientific Company .....
101 E. Gloucester Pike, Barrington, NJ 08007
OPTICA b/c .....
4100 MacArthur Blvd., Oakland, CA 94619
(415) 530-1234

MIRRORS — CUSTOM MADE

Coulter Optical Co. .....
54121 Pinecrest Rd., Idyllwild, CA 92349
(714) 659-2991

MIRRORS — FLATS

Coulter Optical Co. .....
54121 Pinecrest Rd., Idyllwild, CA 92349
(714) 659-2991
Edmund Scientific Company .....
101 E. Gloucester Pike, Barrington, NJ 08007

MIRRORS — DIAGONALS

Coulter Optical Co. .....
54121 Pinecrest Rd., Idyllwild, CA 92349
(714) 659-2991
Edmund Scientific Company .....
101 E. Gloucester Pike, Barrington, NJ 08007
Meade Instruments Corporation .....
1675 Toronto Way, Costa Mesa, CA 92626
(714) 556-2291
OPTICA b/c .....
4100 MacArthur Blvd., Oakland, CA 94619
(415) 530-1234
W.R. Parks Co. .....
P.O. Box 6683, Torrance, CA 90504
(213) 532-6066

MIRRORS — OFF-THE-SHELF

Coulter Optical Co. .....
54121 Pinecrest Rd., Idyllwild, CA 92349
(714) 659-2991
Meade Instruments Corporation .....
1675 Toronto Way, Costa Mesa, CA 92626
(714) 556-2291

MOUNTINGS — COMPLETE

Celestron International .....
2835 Columbia St., Torrance, CA 90503
(213) 328-9560
Edmund Scientific Company .....
101 E. Gloucester Pike, Barrington, NJ 08007
Meade Instruments Corporation .....
1675 Toronto Way, Costa Mesa, CA 92626
(714) 556-2291
W.R. Parks Co. .....
P.O. Box 6683, Torrance, CA 90504
(213) 532-6066

MOUNTINGS — PARTS

Edmund Scientific Company .....
101 E. Gloucester Pike, Barrington, NJ 08007

OPTICAL ABRASIVES — BULK

Edmund Scientific Company .....
101 E. Gloucester Pike, Barrington, NJ 08007
OPTICA b/c .....
4100 MacArthur Blvd., Oakland, CA 94619
(415) 530-1234

OPTICAL TEST EQUIPMENT

Coulter Optical Co. .....
54121 Pinecrest Rd., Idyllwild, CA 92349
(714) 659-2991
Edmund Scientific Company .....
101 E. Gloucester Pike, Barrington, NJ 08007

PREFORMED TOOLS, LAPS

Edmund Scientific Company .....
101 E. Gloucester Pike, Barrington, NJ 08007

SETTING CIRCLES

Edmund Scientific Company .....
101 E. Gloucester Pike, Barrington, NJ 08007
W.R. Parks Co. .....
P.O. Box 6683, Torrance, CA 90504
(213) 532-6066

TELESCOPE ACCESSORIES

Celestron International .....
2835 Columbia St., Torrance, CA 90503
(213) 328-9560
Edmund Scientific Company .....
101 E. Gloucester Pike, Barrington, NJ 08007
Meade Instruments Corporation .....
1675 Toronto Way, Costa Mesa, CA 92626
(714) 556-2291

TELESCOPE PARTS

Dodd Co. .....
7795 W. Ridgewood Dr., Parma, OH 44129
(216) 886-2828
Edmund Scientific Company .....
101 E. Gloucester Pike, Barrington, NJ 08007
Meade Instruments Corporation .....
1675 Toronto Way, Costa Mesa, CA 92626
(714) 556-2291
OPTICA b/c .....
4100 MacArthur Blvd., Oakland, CA 94619
(415) 530-1234

TELESCOPE TUBES

Edmund Scientific Company .....
101 E. Gloucester Pike, Barrington, NJ 08007
Meade Instruments Corporation .....
1675 Toronto Way, Costa Mesa, CA 92626
(714) 556-2291
W.R. Parks Co. .....
P.O. Box 6683, Torrance, CA 90504
(213) 532-6066

TELESCOPES, COMPLETE

Celestron International .....
2835 Columbia St., Torrance, CA 90503
(213) 328-9560
Coulter Optical Co. .....
54121 Pinecrest Rd., Idyllwild, CA 92349
(714) 659-2991
Dodd Co. .....
7795 W. Ridgewood Dr., Parma, OH 44129
(216) 886-2828
Edmund Scientific Company .....
101 E. Gloucester Pike, Barrington, NJ 08007
Meade Instruments Corporation .....
1675 Toronto Way, Costa Mesa, Ca 92626
(714) 556-2291
W.R. Parks Co. .....
P.O. Box 6683, Torrance, CA 90504
(213) 532-6066

◄37 Letters

don't really consider proprietary to myself or anything, and I'm willing to share them. They do such things as MTF vs. arc-sec, MTF for defocus, MTF for central obscuration, MTF for spherical aberration (third order only), spot diagram generation, 3rd order analysis, and H-tan U' plots.

Also, a friend of mine and I wrote a full Damped Least Squares Lens optimization program (aspherics to 6th order) that would be bold, if not fun, to publish. *Sky & Tel.* is not interested in listing programs since Ashbrook didn't "like" to see listings in "his" magazine.

They are written in Basic for an HP-9830 so they should be pretty well universal. The optimizer is in Fortran, and has about 2000 statements.

Let me know what you think. I could always just publish the outputs and have people write for the programs, but I don't want to get myself into postage problems that way.

Thanks for taking time to read this lengthy letter. I wish your magazine a long healthy life. Hope it doesn't go down the old chute like *Telescope Making Technique* did.

Mike Jones
1824 Las Vegas Trail
Ft. Worth, TX 76108

Dear Mr. Jones/ We would love to publish some of your programs in TM. Lots of TM people are fascinated with optical design, the big danger being (as Bob Cox has pointed out many times) you can make silly mistakes — such as designing refractive elements with negative thicknesses. Their performance looks good on paper, but....

The greatest problem I forsee is fitting a 2000 statement program and its documentation into the space we have available. Hoping to hear from you shortly.

Sir / I have read with interest your Editorial leader to TELESCOPE MAKING No. 7. I would like to suggest that if you do decide to open up this excellent magazine to advertising, that you confine it to a set of "pull-out" pages in the centre of the journal. These could well be coloured blue. I believe that this is the best solution because the reader then has the opportunity to see new equipment form both small and large concerns alike, but their position will not disrupt the articles printed in the main part of the magazine. Indeed, if the larger firms wish, they could use full colour spreads in the centrefold! Also, those readers who do not like to be influenced by the advertisements can simply pull out and throw them away!

I hope that these notes have been of some help to you and I trust that you will keep the main part of TELESCOPE MAKING free from commercial glare.

Peter Mack
President,
Manchester Astronomical Society
Manchester, M60 1QD
England

We do not intend to mix the advertising and the articles in TM. TM ads, such as they will be, are primarily to aid our readers.

Note from "Down Under"

Sirs/ Thank you for a very exciting and informative issue #7. The article on improving telescope performance is really great, especially since I am just beginning design on an 8" f/6 telescope.

I think that advertising in TM would be a good thing if it were of the type suited to the special needs of TMs. For instance, special coatings, materials, services, and supplies — not the general ads which are already in ASTRONOMY.

The article on Lord Rosse's Great Telescope was one of the best I have read. It would be a good idea to include such historical reports every now and then. On amateur events, I feel most of those are best left to the pages of *S&T*, except for special reports (on telescopes, of course) about Stellafane and Riverside.

By the way, could you or your readers help me locate a source of supply of either Pyrex or plate glass blanks suitable for making a 20 to 24-inch scope?

Thank you for a very enjoyable magazine. I am already putting TM #7 to work and am looking forward to #8.

Fred L. Redburn
25 Netherwood Rd.
High Wycome
Western Australia 6057

P.S. Would you please send me information on submitting articles to TM? What are your manuscript requirements, and for photos, do you want slides, color prints, B&W, or negatives?

Mr. Redburn/ For TM, we prefer articles typed with wide margins, and lengths running from 500 to 2500 words. We're not fussy, really. Diagrams and drawings are very important for conveying information, and should be black ink on heavy white paper. (You have no idea how difficult it is to shoot from blue ball point pens on yellow paper.) For photos, if you can manage it, please send 5x7 or 8x10 black and white prints. Color prints are next best, then negatives, then slides (we seldom get passable reproduction from submitted slides).

DEEP-SKY OBSERVERS!

GET MORE OUT OF YOUR OBSERVING!

DEEP-SKY MONTHLY is the monthly magazine intended for the deep-sky observer. It's the only place you'll find clusters, galaxies, and nebulae reviewed in depth, month after month, for your observing satisfaction. It's chock-full of sketches, excellent amateur astrophotos, charts, and scientific vital statistics that will help you every time your turn your telescope to the sky.

DEEP-SKY MONTHLY's feature articles cover observing techniques, scientific knowledge about deep-sky objects, special objects of interest, variable stars, and deep-sky astrophotography techniques. Regular monthly departments cover double stars, clusters, nebulae, and galaxies. Whatever your deep-sky observing interests, you'll be pleased with **DEEP-SKY MONTHLY.**

Start your subscription today.

$9/year USA - $12/year elsewhere

photo by Jack Newton

DEEP SKY MONTHLY, INC.
A Non-Profit Corporation of Deep-Sky Astronomers
104 Oakhill Drive, Oxford, Ohio 45056
Dave Eicher, Editor Telephone (513) 523-5554